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SCIENCE AND THE SOCIAL STUDIES, TWENTY-SEVENTH YEARBOOK OF THE NATIONAL COUNCIL FOR THE SOCIAL STUDIES 1956-57.

BY- CUMMINGS, HOWARD H.

NATIONAL COUNCIL FOR THE SOCIAL STUDIES,WASH.,D.C.

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THIS YEARBOOK IS DIRECTED TOWARD EDUCATORS WHO ARE INTERESTED IN BRIDGING EXISTING GAPS IN THE RELATIONSHIPS BETWEEN SCIENCE AND TECHNOLOGY AND SOCIAL STUDIES IN THE SCHOOL CURRICULUM. THE VOLUME REPRESENTS THE COLLECTIVE EFFORTS OF WORKERS BOTH IN AND OUTSIDE OF THE FIELD OF EDUCATION. IT IS DIVIDED INTO THREE PARTS. PART 1 DEALS WITH SUCH TOPICS AS (1) THE SOCIAL STUDIES IN A SCIENTIFIC AGE, (2) SCIENCE AND THE SOCIAL STUDIES, (3) THE USE OF SCIENCE AND TECHNOLOGY IN IMPROVING LIVING CONDITIONS IN UNDERDEVELOPED COUNTRIES, AND (4) THE INTERNATIONAL GEOPHYSICAL YEAR. PART 2 DISCUSSES (1) SCIENTIFIC RESEARCH IN THE UNITED STATES AND THE NATIONAL SCIENCE FOUNDATION, (2) SCIENCE TRANSFORMATIONS IN AMERICAN AGRICULTURE, (3) RESEARCH IN THE MEDICAL SCIENCES, AND (4) APPLIED ATOMIC ENERGY RESEARCH. PART 3 ENCOMPASSES (1) SCIENCE AND SOCIETY--INTELLECTUAL AND SOCIAL IMPLICATIONS OF SCIENCE AND TECHNOLOGY FOR DEMOCRACY, (2) SCIENCE AND SOCIAL STUDIES IN TODAY'S ELEMENTARY SCHOOL, (3) THE INTERRELATIONS OF SCIENCE AND SOCIAL STUDIES AT THE SECONDARY LEVEL, (4) TEACHER EDUCATION, AND (5) A LOOK TOWARD THE FUTURE. APPENDED ARE (1) SOCIAL ASPECTS OF SCIENCE--PRELIMINARY REPORT OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE (AAAS) INTERIM COMMITTEE, AND (2) CONTRIBUTORS' WHO'S WHO. THIS DOCUMENT IS ALSO AVAILABLE FOR $4.00 FROM THE NATIONAL EDUCATION ASSOCIATION, PUBLICATIONS SALES, 1201 SIXTEENTH STREET, N.W., WASHINGTON, D.C. 20036. (DS)

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Science
and
The Social Studies

HOWARD H. CUMMINGS
Editor

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THE SOCIAL STUDIES
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HOWARD H. CUMMINGS, *Editor*

1956-57
Twenty-Seventh Yearbook

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Preface

THE APPEARANCE of this volume is timely. It should be welcomed by teachers, supervisors, administrators and all others concerned with curriculum development. Quite properly, the authors do not attempt to provide "pat" solutions for problems of relating the sciences and the social studies in school programs. But the Yearbook does make it clear that the natural sciences and the social sciences are not independent of each other and that the progress of society is intimately bound up with both. Whatever the organization of the curriculum, the sciences and the social studies cannot be completely separated. The impact of science on society is a social phenomenon. The effects of scientific progress on technology, agriculture, health and war are social. They must be reckoned with in the social studies.

The National Council for the Social Studies is much indebted to the editor of the Yearbook, Howard H. Cummings. It was no small task to develop and gather the ideas, to organize them, and to secure an array of experts to set them forth, such as the authors of these chapters. To them, also, the Council and the profession are grateful. The editor and authors have labored in this project without financial reward. Their product is a substantial contribution to the cause of education for freedom. It is received with deep appreciation.

It should be noted that the publication date of the Yearbook has been changed from November to March. This action was taken by the Board of Directors in 1956 after long deliberation. The purpose was not, as some have suggested, to have the last digit in the number of the Yearbook be the same as that in the year of its publication. The previous situation concentrated too great strain on the resources of the national office during the fall, as it was required to see the Yearbook through its final stages at the same time that it made the last-minute preparations for the annual meeting. This matter is now remedied. Another desirable product of the change is that the Yearbook now appears early in the year of its copyright.

WILLIAM H. CARTWRIGHT, *President*
The National Council for the Social Studies

Foreword

THE role of science and technology in American society is so obvious that any child growing up in our culture would understand a great deal about the part it plays without instruction. At the same time there is a grave doubt that any of us, children or adults, have been able to absorb fully the implications of the discoveries and changes made since the present high school pupils were born. Wonder drugs, the Salk vaccine, planes which break the sound barrier, guided missiles, automation, TV, and atomic energy are the well-known highlights of the news over a brief one-half of one generation. A knowledge of many others is limited to specialists, and an unprecedented amount of research drawing on the whole of accumulated scientific knowledge promises to continue the string of new discoveries and new adaptations and uses.

This Yearbook has been written with a great deal of humility. The social, economic, and political implications of the great discoveries of this century are not easy to understand. An account of exactly how the many scientists work to make these discoveries is not easy to write. Just what to teach about science and technology in social studies classes is not easy to decide and is difficult to plan. Certainly it is not the responsibility of the social studies teacher to develop scientists. But it is his responsibility to help his pupils learn to live in a world where each day science becomes more important. Social studies teachers have felt for a long time that scientists and members of the scientific professions should know more social studies. It would be an egotistical social studies teacher in this day and age who would deny the reverse of this often repeated statement, namely that social studies teachers should know more about science.

Great educational changes are seldom made by a few authors writing a yearbook. Hundreds of teachers must study thousands of hours and carry on years of classroom experimentation before defensible patterns begin to emerge. It is the hope of the authors that this Yearbook may help in this study and experimentation and will encourage those who have not begun such work to take part in the great task of integrating science into our culture.

The editors express thanks especially to those authors who are not members of the educational fraternity who have prepared the chapters on The National Science Foundation, the story of science in agriculture, the research in health, the experimentation in atomic energy, and the account of the International Geophysical Year.

To the authors who are workers in the field of education, thanks are expressed also. From all the authors there is an unspoken hope—that the reader will take hold in his classroom and help the pupil add more depth to his knowledge of this world of science than most people have today.

HOWARD H. CUMMINGS, *Editor*

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PART ONE

CHAPTER I

The Social Studies in a Scientific Age

Howard H. Cummings

The educational scene in each decade of our recent history has been dominated by a major emphasis. The social studies program as we know it today was born in the decade 1910-1920. This decade might be called the Golden Age of Political Science. The social studies movement came into its own during this decade which saw four amendments added to the Constitution, the League of Nations established, the great reform movements carried forward and a national concern for good citizenship developed. The 1920-1930 decade belonged to history. The great "debunking" movement was the general public's view of a general movement where scholars revised and expanded the view of America's past. The fact that Van Loon's *Story of Mankind* and H. G. Well's *Outline of History* were best sellers during these years is evidence that the interest was not entirely national in character.

History gave way to sociology in the decade of the 1930's. Social sensitivity to problems in the present replaced some of the interest in the problems of the past. However, the public mind was shocked not only by the depression at home but by the rise of totalitarian governments abroad. The values derived from American tradition of freedom and of American political institutions served to incorporate history and political science into the process of learning about economic and social change.

The decade of the 1940's saw a major interest in psychology. Social psychology grew as a major discipline in the social science field. The demands for training for citizenship were modified by the needs of children and youth for personal and social adjustment.

The intellectual character of a decade is best seen in retrospect. After the camera eye, which has informed the public, had shifted to a new focus the sequence of pictures just completed usually make up a pattern. However, there seems to be little need to wait until 1960 to name the decade of the 1950's as the age of the physical and biological sciences.

Historians who like to date their movements can probably pick out certain events which mark the end of an era. When the Senate on November 19, 1919 refused to ratify the treaty bringing the United States into the League of Nations, the great era of political reform seemed to have ended. On October 29, 1929 the stock market crash shifted public attention from the past to the present. On June 22, 1940 when the French signed an armistice with a victorious Hitler the public mind shifted to a physical and psychological preparation for another world war. The date for the age of science can be fixed on September 23, 1949. On that date President Truman announced that there had been an atomic explosion in the U.S.S.R. and the American people must assume that their Russian rivals also had an atomic bomb. The uneasy interlude of atomic monopoly which had existed since August 1945 was over. Two great rival powers, each serving as a magnetic pole which drew lesser powers toward their international policies of world communism or world democracy, now possessed the weapons to destroy not only each other but a good part of the rest of the world as well. Science and technology suddenly appeared as the first necessity for preserving American leadership in the free world—if not for survival.

Since the early 1940's there had been warnings that the American people might be forced into a scientific race and some questions had been raised as to how well prepared they were to enter such a contest. The beginning of World War II dramatized the fact that many of the great basic discoveries in science had been made by the graduates of European universities. The possibility that the flow of ideas from the universities should cease and America should have to fall back on its own resources was explored. Out of this discussion eventually emerged the proposal for a National Science Foundation. The short history of this new organization, first proposed in 1945 and established by law on May 10, 1950, is told in Chapter V. An idea was translated into a government organization with adequate financial support in the relatively short period of 10 years.

It is worth noting that the advisability of including the social sciences in the program of the National Science Foundation was explored during the Congressional hearings on the bill and the decision was made not to include this area in the research program which should be paid for from federal funds. At this time research in the physical and biological sciences is supported by public grants while research in the social sciences still depends on university and private foundation grants alone.

In view of the public interest in science it would be easy for the social studies teacher to view his science colleague as a formidable and currently successful rival in the educational field. But even friendly rivalry is a poor substitute for collaboration. The social studies teachers have always been sensitive to public interest in building a school program. Each decade has seen a revision movement which tried to include materials and experiences which would help pupils learn about the public problems which were of major concern to the citizens at that time. Government, history, sociology and social problems, the psychology of group work and group living have seen a revision or amplification of their roles in the process of social education. To be sure the changes were seldom sweeping enough or the time allotted long enough to satisfy the advocates of the new viewpoint. But there were enough changes to satisfy the thoughtful patron of the schools after the major public interest had shifted to a new subject.

Periodically some member of the social studies fraternity discovers that there is a neglected area in the program. An inventory has been made of the knowledge and information needed to help a pupil understand and live in contemporary society. A second step is to match this inventory against the existing curriculum. If the curriculum does not include some of the knowledge required, a neglected area appears. In current discoveries two such areas are frequently mentioned. One is a need for more knowledge about Asia which is now playing a larger role in world affairs. A second neglected area is the need for more knowledge of science and technology which is playing an increasingly larger role in contemporary global society.

CURRENT STATUS OF SCIENCE IN SOCIAL STUDIES

A sober review of the social studies program over the last 50 years will reveal the fact that the role of science and technology in modifying society has not been overlooked in the social studies program. A cursory examination of an American history textbook used at the beginning of the century reminds the reader that Benjamin Franklin, Robert Fulton and Eli Whitney had their places in the nation's early history. Elias Howe, John Ericsson, Cyrus McCormick, Alexander Bell, and later, Thomas Edison and Luther Burbank were added. The men were listed as inventors and there might be some who would say they were not scientists but the line between pure and applied science is rather hard for even scientists to draw. James Watt probably supplied the theoretical scientists with at least as much theory as he received from them. In this rather fine area of definition the social studies teacher concerned with the impact of science on society need not become deeply involved.

Later textbooks shifted the emphasis to the development of different technological fields such as transportation, communication, manufacturing and agriculture. But here the contribution of individuals in developing these fields was retained. The story of the Panama Canal and the conquest of yellow fever were included as technical and scientific achievement to which Americans might point with pride.

In recent times there has been a steady infiltration of accounts of scientists and their contributions into world history textbooks. The stories of Copernicus, Newton and Galileo and their contributions in bringing our modern age into existence are included. The story is picked up again with James Watt and then skips to Darwin. In some books Louis Pasteur and Madame Curie appear near the end.

There have been relatively few attempts to write the stories of groups of scientists around the development of central theories and major technological change which came into existence as a result of their work. World history is a crowded course. There is never enough time to teach all the story of the past which is useful for an understanding of contemporary society. History was originally written as a chronicle for political and military leaders, and a strong political and military emphasis remains as part of the tradition. Some knowledge about the great story of the growth of European civilization from its beginning in the river valleys of Egypt and Mesopotamia until it was transported to Santa Fe, St. Augustine, Jamestown and Plymouth is necessary if Americans are to understand their own language, religion, fine arts and philosophy. There is a current demand for the inclusion of the history of the Asian countries, Latin America and Africa in order to encourage a world view. If the story of science and technology in world civilization is to be included with the larger world story, a radical revision of the present world history course is needed.

In civics textbooks and textbooks on American problems, the government organizations which are engaged in scientific work are described. The dates they were authorized by Congressional authority provide some date lines that indicate the time at which various scientific and technological activities became important in the public mind. The Public Health Service dates from 1798 and the Patent Office was established 1836. A grant from an English philanthropist established the Smithsonian Institution in 1846. The post Civil War years saw the Weather Bureau established in 1870; the Geodetic Survey expanded to its present over-all survey and mapping responsibilities in 1871 and the Geological Survey was set up in 1879. The Bureau of Standards was established in 1901. The boards and commissions on communication and aeronautics followed the development of the radio and aeroplane.

Little attention is given in the social studies textbooks to the growth of scientific research in the universities, or the expanding research contributions made by industry or the contributions of the great scientific societies already mentioned. The American Association for the Advancement of Science was organized in 1848 and the several branches of science and engineering have organized societies for the promotion of research and technical knowledge in the several scientific and technical fields.

Science and invention have had their American pioneers. The early scholars and inventors were not a part of large universities, large government bureaus nor large industrial laboratories. They were usually free-lance scholars or inventors who often had to earn a livelihood while they carried on research. Many of them helped to build the institutions which now carry on the large and continuing studies which they pioneered. Maury was a naval officer writing a textbook for naval officers when he began his study of ocean currents. Henry had independently prepared his study of electricity to about the point reached by Faraday before he became the first head of the Smithsonian Institution. Beaumont and Morton made their contributions to medicine as practitioners. Audubon, Muir and John Burroughs and the whole group of naturalists taught Americans to appreciate and enjoy their heritage of nature. With many other biological scientists and geologists they were responsible for awakening public interest in the national domain which later developed into the conservation movement.

SOME GUIDELINES FOR THE SOCIAL STUDIES

If we conclude that social studies courses in the past have not been adequate for providing a pupil the knowledge needed to understand the complexities of a scientific technological society two questions immediately arise:

1. What are the new objectives or goals that must be stated to provide a pupil with the opportunity to learn the concepts necessary for understanding the life of a society which is strongly influenced by science and technology?
2. What content and method should be used to provide learning experiences to reach these goals or objectives?

In answering the first question on the nature of the goals and objectives a negative note is in order. It is *not* the responsibility of social studies teachers to develop research scholars in the physical and biological sciences. Nor should there be any thought given to converting the social studies program into part of a pre-engineering course or related courses for the vocational training of technicians. Science and technology have not become so all-important that they must become the center of our total educational effort.

A second general note of a more positive nature is also needed. Generations of pupils and their teachers have viewed academic education as a two-track enterprise. The broad highway of general education came to a fork at about the 10th grade. One branch then ran away in the direction of mathematics and science, the other toward English, classical or modern languages, art, music and social studies. The mathematics road was mostly for boys. It was a steep road up which the scientifically talented sprinted and future engineers toiled. The toilers often left the road and cut across country to travel on the other highway. The language-arts-social-studies highway attracted the large majority of the girls and the boys interested in future careers in law or business. There has been a fairly strongly held view that one road or the other had to be picked at about the age of 16. Teachers of mathematics and science have in some instances been guilty of a feeling of smugness because they taught hard courses to above-average pupils and maintained high standards. The arts, language and social studies group could always repair any injured feelings by remembering that they were the custodians of the great cultural tradition of Western civilization and that their courses represented the humanities even though the courses had been modified considerably to meet the American need for universal secondary education.

At this point it is necessary to stop and indicate that it is not the purpose of this Yearbook to prepare a broad program of integration where subjects would be dropped and a core curriculum based on general learnings or problems of living which draw from all areas would replace the present program. Whatever its virtues, such a unified approach to understanding the world about us must be viewed against the problems which must be solved to make it effective. Teachers who know how to teach the several skills of language and mathematics, the concepts of science and the social sciences, history and an appreciation of literature are rare. Experimentation toward developing such teachers for unified courses will have a better chance of success when there is no teacher shortage and when major revisions in special subject areas which must be made have been completed. In the meantime the final educational outcomes for the pupils may be broader if all teachers can take a broader view of education than the confines of a single subject field and can point out relationships with the other subjects the pupil is studying. Integration in the final analysis must take place in the mind of the learner. Relationships are less likely to be seen in classes where the teachers view another subject field with indifference if not with cold distaste. In Chapter XI the problem of broadening the education of social studies teachers to include some knowledge of science and technology is discussed. Without waiting for formal courses in teacher education practicing teachers can begin their own re-education along the lines the author has suggested.

The social studies teacher will want to focus the attention of his class on man and his problems in society rather than on the abstractions of scientific theory or the specialized mechanics of the technologist. These areas can be left to the teacher of science. The following goals are prepared to define the area in which the social studies teacher may teach to help his pupils learn more about the work of scientists and technologists and the place of their work in influencing the culture in which the pupils live.

1. *There is a need for a more complete integration of science into American culture.*

Many nonscientists still regard science as an impossibly difficult subject to understand. A few even dislike science as a materialistic threat to their values. In times past there has been talk of a moratorium on scientific discovery until the social forces at work could catch up with the discoveries that had been made. It is probably safe to predict that pupils will learn more about science and the related subject of mathematics than they have in the past. But the problem of relating what is learned about science to the problems which pupils must learn about how men live together in human societies is the special province of the social studies teacher rather than the science teacher. There is a need for better communication between the two teachers and for a division of labor to work on this over-all task of general education. Some of the authors who have contributed to this Yearbook were willing to take the time to write a chapter only because they believed the Yearbook was a step in the direction of integrating science into the culture. They recognized this as one of the most difficult educational tasks facing the American public but at the same time the most important.

Let us recognize at once that the American people are not illiterate in the field of science or inept in the area of technology. On the contrary their knowledge of science and their skill in operating and maintaining their machines is unexcelled by any large population anywhere. They also have more machines and are exposed to more of the impact of scientific discovery than other people. The question is not are they good? but are they good enough?

2. There is a need to understand how scientists have worked in the past to discover knowledge, and how they are currently working to amplify and refine existing theories and to formulate new areas.

There has been general agreement by the authors of the several chapters of this Yearbook that there is no one scientific method. As good an explanation as any for the way they work is to say they pick up ideas from long studies on a problem and work to verify and prove the hypothesis which they build up. In Chapter II the case history method for studying major scientific discovery is discussed. This method, discussed by James M. Conant in his lectures, advises the laymen who would understand science to trace the growth of some major discovery as successive men work on some problem. Teachers who know how to organize content into teaching units need not wait for some science historian to write the history of thermodynamics, electricity, genetics or modern bacteriology before beginning to teach case history in those areas. The encyclopedias already contain accounts of the historical development of those areas and the biographies of the men who worked to develop the ideas back of these important scientific fields can be read to fill in the story. In electricity the names of Ohm, Ampere and Volta have become a part of the language to describe the transmission of electrical current. The names are used daily by every electrician although the men themselves are known to only a few scientists.

It is difficult for a layman to follow the steps of contemporary research but much less difficult to follow research which has been completed. The attitude of many laymen that science is so difficult that it can be understood only by men of genius tends to put scientists in the category of miracle men. Historical study of past discovery and invention which has become an integral part of our daily thinking and living may bring science down to earth in the thinking of pupils and remove scientists from the realm of supermen to the same world in which the rest of us live.

3. There is a need to study the role of science and technology in our life today as one of the important aspects of modern citizenship.

A few figures may help us to begin our thinking on the citizenship aspects of science. In 1955 the total sum spent in the United States for research and technological development was $5.4 billion. Of this sum $80 million came from the universities, $2.6 billion was spent by industry and $2.72 billion was spent by government. In other words the citizens of this country by public decision spent $2.72 billion for research in science and in scientific development. The three chapters on agriculture, health and atomic energy report some of the scientific achievements made with public funds. The reader will recognize from the statistics presented here that public expenditures were almost matched by private expenditures for research and development. In the actual use of the funds government spent $1 billion; industry, $3.95 billion; and the universities, $450 million. Scientific research is a three-way partnership, both in the source of funds and their use.

What are some of the decisions which must be made by the members of Congress and the officials of the executive department whom the citizens of this country elect?

The work of the government in the field of science is not new. Research has been going on for a long time. The recent changes have been in the direction of more research either sponsored or conducted by government rather than a change from none to a great deal. This is one of the decisions which the citizens of the United States have made. One of the questions still unanswered is what is the role of the scientist as an employee of the government or of industry or as a professor in a university? How much should he be paid? Who owns his discoveries or his inventions after he has made them? How much secrecy shall surround his work? Shall his findings be published for all the scientists of the world to read or shall they be kept secret? Will the world conditions which make necessary a high measure of secrecy in the field of atomic research in the interest of national security put too much personal pressure on the scientists who work in this field?

These questions and many others have been discussed among scientists in their own journals and many of them are discussed in the daily press as they become matters for public concern and decision rather than for decisions among the members of the scientific fraternity.

A second type of question clusters around the problem of what areas should receive most attention in the total research program. Atomic research and development was begun on a large scale as a war measure and has been continued in large part as a measure of national defense. It may become a new source of power which will open up a new era as the utilization of coal, through the steam engine, brought a great industrial revolution in the 19th century. In view of this prospect should research on the better utilization of coal, the extraction of petroleum from shale and the utilization of solar heat for power be discontinued? The falling water table in the United States and the great arid wastes next to the world's oceans point to the need for a scientific discovery for utilizing salt water for irrigation, industrial and domestic use. The conquest of disease is by no means complete. The work of the biological scientist to control animal and plant diseases seems to be unending. A higher standard of living seems to depend on increasing productivity by the continuous invention of new machines. The number of problems far exceeds the number of scientists available to carry on a large scale job of cooperative research and development for successful solutions. Some system for setting up priorities is needed and, since public decisions will determine many of the priorities, the long-range and social value of such a list will depend upon public wisdom.

Finally in our concern over the solution of immediate problems we should be careful not to starve, or force into some area of research where he is not interested, the scholar who is interested in pure research. Our history lessons have been adequate for teaching us that the world of science of today is built upon discoveries which at the time they were made were viewed as interesting but possessing no utility. In Chapter IV there is a plea for the scholar who is interested solely in knowledge for the sake of knowledge. The billions being spent on research should include the work of many of these scientists in the subsidies voted. But a public awareness is needed of the value of what in the past has been called pure research to extend the boundaries of scientific knowledge.

The value of the scientific component in citizenship education is equally important when considering international problems. Two recent dramatic examples will be recalled at once: One is the atomic race between the United States and the U.S.S.R. which is revolutionizing armaments while thermonuclear bombs, planes of supersonic speed and guided missiles are developed. The second is the Point 4 Program which is furnishing technical assistance to underdeveloped countries to help raise standards of living.

The "Atoms for Peace" promises a broader approach to the solution of international problems. The creation of a European atomic community, Euraton, including six European nations with a total population of 165 million in 1957 marked the beginning of a cooperative approach to the use of atomic energy. The debate over the right of any nation to carry on tests of new atomic weapons which added to the amount of radioactivity in the earth's atmosphere raised a new issue in international relations, and one in which the evidence of trained scientists would be necessary to establish how much danger to the health of all the people in the world was created by any one nation's decision to test new weapons.

4. *There is a continuous need to reduce any lag which perpetuates social and political practices which have become useless if not harmful as a result of new scientific thought or technological change.*

The study of a society with its changing social, political and economic problems is pre-eminently the field of the social scientist, not the physical or biological scientist. A corollary to this statement is that the responsibility for teaching pupils about the social, political and economic problems is the responsibility of the social studies teacher rather than the teacher of science. Let us recognize the scientist as a man with an able and often brilliant intellect, but no man is omniscient and the scientist is a man. Fields of scholarship are highly specialized and long experience and some measure of success in one field does not always add to general intellectual competence in all fields. In recent years men of science have become increasingly active in public debate and their activity should be welcomed by all. However, there is no need for the social scientist or his associate in the social studies field to abdicate and leave the solution of social, economic and political problems to the scientists. The exact opposite is needed; more research in the social sciences, and better teaching in an improved social studies program.

The problem of changing a social studies program to meet the new conditions which technological change bring about is not a new one. The cultural lag is a familiar term to social studies teachers. The concept of a shrinking world which continues to be contracted by the speed of transportation and communication has been taught for at least a generation. The impact of the automobile, tractor, movie projector, radio, T.V., electricity and countless other machines on our ways of living have been topics for study in social studies classes. The growth of scientific and mechanized warfare has been studied from the first use of gunpowder to the present threat of human annihiliation if the great powers should drift into a world war where all atomic weapons would be used. A short reminder is sufficient to recall the scope and age of the problem. There is no need to expand the list to belabor the point.

Scientists make discoveries and inventors use them to build machines. Neither can predict or control the social effects of the products of their minds. In fact until 1945 when the first atomic explosion took place at Hiroshima many scientists felt that they had no responsibility for the discoveries that they made. Their general attitude was that, if the minds of a few men could produce important discoveries and inventions, the minds of all men should be good enough to find a way to use these discoveries and inventions to prolong and improve human life rather than to destroy or degrade it. A contemporary view is that the scientist does have responsibility for the social effects of his discoveries because of his special knowledge of the power of his idea for good or evil. But his control over his idea ends when he reveals his discovery. After that the collective good sense of mankind is the only guarantee for general benefit and the only defense from public harm.

Responsibility of Social Studies

It is at this point that the responsibility of social studies teachers begins. International control of atomic energy is a political problem, not a scientific one. So it goes with a long list of problems which scientists have created, but for which social scientists must prepare tentative solutions. Some of the science-related problems which have piled up in front of the social scientist and the social studies teacher may be examined briefly:

1. *The need for a world ban on atomic weapons of all kinds is clearly recognized.* This serious problem may be mentioned very briefly. Events in this case have been the great educator. All men have been able to see, even through a veil of secrecy, the future possibility of total destruction in a total war fought with total weapons.

The atom is being put to peace-time work as described in Chapter VIII. However, current use is probably only a beginning. In war scientific discovery erupts powerfully and destructively. In times of peace the advent of a discovery is usually gradual. The new machine or the new process infiltrates but seldom innundates the current order of things. It is probably safe to predict that the large scale use of atomic energy in the world will follow this pattern. The problem will not be, as in war, to use or not to use but rather when, where and how to use this new source of energy.

2. *A second problem in which science and social science join forces is in the enormous task of providing more food and better health for all people of the world.* As long as one-half of the people of the world go through life more or less hungry and one-half of the people in some countries suffer chronically from disease, there is little hope for a better social organization, a stable government or an effective economy. Conversely more food and adequate medical services alone will not automatically usher in an age of modernity for a feudal society. Science and social science both must be used to bring into existence a world society which has achieved some measure of homogeneity

through sharing many of the benefits of science and technology in a free society.

Above the minimum standards for health and nutrition rise the aspirations of many people for a higher standard of living. Better clothing, shelter, mass entertainment, transportation and a large measure of leisure to enjoy these things rests on mechanization. But history is full of examples where technology has been used to exploit rather than improve the living standards of many people. Modern machinery used without a social conscience or the know-how of the social scientist can be used to remove the natural resources of minerals and timber very quickly leaving behind the same poverty that existed before the machines were brought in, with a measure of bitterness and depravity added.

3. *One of the first areas to receive attention in any country when a machine age is introduced or where the tempo of mechanization is increasing is education.* Worldwide changes in education are going forward today to meet the demands which have been created by science and technology. In most of the underdeveloped countries two movements are growing to meet this demand. One is the movement for universal literacy, the second is a movement to start technical and vocational high schools. In many countries there is a serious imbalance in secondary and higher education. These countries have a surplus of educated manpower and a shortage at the same time. Too many people have been educated as philosophers, classical scholars and government officials; too few as scientific agriculturists, engineers, physicists, doctors, nurses, home economists and veterinarians. There are too many clerks waiting for government positions and too few plumbers and electricians. Prestige and tradition have confined education to a channel far too narrow to provide all the competencies which a scientific-technological society requires.

In the United States the problem is somewhat different. Mass production came of age in America. Problems which are just appearing in other countries have been present here for a generation. A second advantage was that tradition did not prevent us from establishing the great land-grant universities almost 100 years ago and the early designation of these institutions as "Cow Colleges" by the educational elite of the day did not prevent thousands of students from completing the curriculums of agriculture, engineering and home economics to earn degrees. The output of the universities kept pace with farm, factory and home mechanization until the beginning of the Korean War in 1950. Since then there has been a shortage of scientists and engineers, and estimates of future graduates against future need place the shortage of scientists and engineers in the year 1965 at 465,000.[1] The serious consequences of this growing shortage are stated in terms of national disaster through loss of our scientific lead in the international armaments race or the collapse of our economy through lack of invention, or both.

MANPOWER NEEDS

Social studies teachers should view the concern about the future manpower needs with a broader view, with a greater measure of balance and proportion than is available at this time in the public press. There are alternatives to armament races in the form of international cooperation. Perhaps the economists can devise methods for an economy to operate other than a steady flow of new inventions and increasing mechanization. Proposals to establish special schools where the most intelligent boys can begin intensive study, at the age of 11, to become scientists, or proposals to make science and mathematics the major part of the programs in all high schools should be carefully debated before action is taken. Little is gained by name-calling and the terms "illiterate engineers" and "learned ignoramus" need not be revived, but at the same time it should be remembered that many engineers and scientists have had highly specialized educations. Their pronouncements on educational policy sometimes ask for a return to the Three R's plus discipline with the emphasis on mathematics and discipline. At this point, in order to indicate that there are a growing number of scientists who are respected educational statesmen, a summary by one of them of the current educational program may be quoted. James B. Conant, an eminent scientist, former President of Harvard and High Commissioner to Germany and Ambassador to Germany was for many years a member of the Educational Policies Commission of the National Education Association. Writing on the subject of American education after his return from Germany in 1956 Dr. Conant wrote:

> . . . There has been an increasing concern in recent years with our failure to educate a sufficient number of scientists and engineers. That is to say, a number sufficient to man adequately our industries and our national defense establishments. The colleges blame the schools for inadequate preparation (particularly in mathematics), and the schools blame the taxpayers for not providing sufficient funds to pay for first-rate teachers of science and math-

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[1] A very valuable learning unit on the problem of manpower can be built around the bulletin of the Educational Policies Commission of the National Education Association, *Manpower and Education*. The bulletin may be obtained from the National Education Association, price $1.25.

> ematics. Both criticisms are correct to my way of thinking, . . . as to the first, the difficulty is in no small part due to our failure to identify at a relatively young age those boys and girls who have more than the average talent for mathematics. If such pupils were identified (and tests for this purpose seem to be at hand) and then were stimulated to proceed relatively rapidly with their studies, a respectable fraction of the incoming freshmen of the better colleges would have sufficient mathematical aptitude to tackle the physics and chemistry courses with both enthusiasm and success. At present, a number of college students who formerly had the ambition of becoming scientists drop out once they run into the difficulties of freshman physics, chemistry, and mathematics.[2]

This proposal to encourage abler pupils to study more mathematics is a reasonable one. Probably most social studies teachers would go along with current proposals to increase the science requirement for graduation from high school from 1 unit to 2 units and agree to a similar increase from 1 to 2 units of mathematics. There can be little question about the fact that science and technology are becoming increasingly important in our culture and that a culture does not maintain itself without education. But the social studies teacher will deny that the teaching of science and mathematics is the sole function or even the main function of the American schools. Dr. Conant believes that we need three changes in our schools: (a) more emphasis in learning about the problems of other people in other countries, (b) more graduates who are able to speak and read a language other than English, (c) more graduates who know more mathematics. His summary is both a tribute and a challenge to American social studies teachers:

> What I have just suggested and the changes I shall later propose for our colleges and universities can be accomplished by modifications in our educational practices so slight that they will not jeopardize the essence of the American tradition in education. We need not retreat one step from our own goal of providing education for all (and I mean all) American youth. For, let me make it plain, I am neither prophesying nor recommending abandonment of those basic principles that characterize our schools and colleges as contrasted with the European. Equality of opportunity for all children and equality of respect among all occupational groups are two doctrines that are as significant for our future as for our past. These are the fundamental premises of American education. Every citizen needs to understand them; every citizen needs to realize how they differ from the premises in other lands.[3]

Social studies teachers have long accepted, and work continually to preserve and extend, the two doctrines stated by Dr. Conant. They even hope that these doctrines may become "articles of export" to help pupils in other lands by providing a greater equality of educational opportunity and a larger measure of mutual respect. In the beginning of this chapter the shifts in emphasis in the social studies program to meet new demands brought on by social changes were discussed. These changes have not altered the central emphasis of teaching pupils how to live in, maintain and improve a free society. Within this framework teachers will learn how to teach more about how the scientific and technical aspects of our culture came into existence, and how these ideas influence the whole culture in which they live.

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[2] Conant, James B., *The Citadel of Learning*. New Haven, Conn.: Yale University Press, 1956. p. 43.

[3] Conant, James B., *op. cit.*, p. 46.

SCIENCE AND PHILOSOPHY

It would be unfortunate if, in the present atmosphere of international competition in the field of science and world interest in the advance of technology, the relation of science to philosophy should be completely ignored. Science in the beginning was a search for knowledge for knowledge's sake. If it had any practical use it was to liberate men's minds. It was the scholar's method for exploring the universe and testing some of the common sense hypotheses which men had long held about it. It takes time for a new idea to spread. The cultural effects of its spread have recently been summarized by Dr. Margenau of Yale University.

> Let me trace in some detail the reaction of science upon man himself, and consider briefly some of the effects of every major scientific discovery. The obvious effect is technological; it is the visible and impressive movement from discovery through commercial development, production of new goods and devices, advertising, and sale, toward the establishment of greater comforts of life. . . . But every truly great scientific discovery launches also another trend, much less apparent and more subtle in its progression from phase to phase through human culture. The discovery, acting as a *fact* in initiating the obvious movement [technology], becomes the lever of an *idea* in the other. It clamors to be understood; it takes on significance and organizing power. The developing theory contains novel features, features contradicting what was previously regarded as true. By virtue of this apostasy the discovery induces a rearrangement of thought in adjacent fields. . . .
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> Results as challenging as these cannot fail to have a profound effect on philosophic speculations. . . . Thus this movement ends in new views on the nature of the universe, the relation of man to the universe and the relation of man to man. Ethics, sociology, politics are ultimately subject to infestation by the germ that is created when a discovery in pure science is made.[4]

Dr. Margenau believes that history shows that human society enjoys greatest stability when the two movements stemming from scientific discovery are in balance. Formerly the technological changes which modified man's standard of living and the intellectual movement which changed his cultural milieu took about the same time to become effective. Each required about a century to become effective. Today the technological movement has been reduced from 100 years to about 10 but there has been no sign of speed-up in the intellectual movement.

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[4] Margenau, Henry, "Why Teach Philosophy of Science." *Age of Science, An Annual Guide to Progress and Opportunity in Science and Engineering*. Bristol, Connecticut: The Hildreth Press. December 1956. p. 30-32.

> . . . Kant, the philosopher who more than any other developed the philosophic framework for Newtonian physics, published approximately one hundred years after Newton. Modern empiricism, which is a philosophic version of the great discoveries in thermodynamics and statistical mechanics of a century ago, has reached its zenith in our time. The scientific revolution that occurred in the atomic field at the beginning of the century—the unprecedented, epoch-making pronouncements of the quantum theory—has not found satisfactory philosophic consolidation to this very day.[5]

Both the technological and philosophic results flowing from scientific discovery are important to teach if a pupil is to learn about the changes brought about in his culture by scientific discovery. Copernicus taught man that the earth on which he lived was not the center of the universe. Darwin explained his appearance on earth as the result of a long period of evolution. Freud taught him that he was less the master of his fate than he had thought. Many other scientists have changed his ideas about his universe, his relations to other forms of life on his planet and his relations with other men. The latest discoveries in science are beginning to modify the direction and the patterns of research in many areas of the social sciences. Via this research the philosophic ideas generated by the latest great discoveries in science will sometime in the future appear to modify the program of the social studies.

Scholars work in a single specialized area of the whole field of universal knowledge. All their findings are related. The social studies teacher selects from the field of scholarship those findings which will help him teach his pupils how to live in the culture into which they were born. Science scholars have made and are making highly important discoveries which are modifying the culture in which pupils learn and live. Some knowledge of how scientists work, what contributions they have made and are making is essential if the social forces at work in contemporary society are to be understood. A complete job of remodeling is always more expensive than constructing a new building but in the social studies where the goals are both continuity and change, remodeling will always be the way we will build. A greater emphasis on science must be incorporated into the existing program and to make room for it some of the old wood, often beautiful and always precious to some, must be removed. Each decade since the 1910's has seen a remodeling in the house of the social studies. Perhaps this last one will be more difficult to make than the others, but when the issues of science and technology have become matters for public decision by citizens and are major factors when individuals make social and economic decisions, the needs for effective citizenship and social competence demand that the alterations be made.

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[5] Margenau, Henry, *op. cit.*, p. 32.

CHAPTER II

Science and the Social Studies

LEWIS PAUL TODD

HISTORY offers the best gateway through which the layman can approach an understanding of science, declared James B. Conant in his small volume, *On Understanding Science.*[1] "Philosophic and mathematical minds will prefer the logical approach," he wrote, "but it is my belief that for nine people out of ten the historical method will yield more real understanding of a complex matter."

Now this is a debatable proposition, being a matter of belief, not a demonstrable fact, but there are persuasive arguments in support of the proposition, and because the author of this chapter shares Dr. Conant's faith in the value of history as a gateway to an understanding of science, some of the arguments for this point of view are presented here. It is important, however, to remember that the subject is the education of the nonscientist, the layman, the student who hasn't the slightest intention of becoming a scientist—and, perhaps at the moment, only the most remote interest in the subject itself.

THE CASE STUDY APPROACH

It is also important to agree at the outset on what is meant here by "history." As anyone who has read Mr. Conant's book knows, he was not talking about a chronological survey of the development of science. He referred, rather, to "the historical method," and he had in mind a series of case studies, a number of which he offers by way of illustration.

Several weeks ago the author received a letter from a science educator, a thoroughly competent scientist in his own right. The letter was prompted by a statement made urging social studies teachers to devote more time and thought to the study of science and technology. The writer began:

> Apparently, we can start with at least one point of agreement; that the social implications of scientific and technological developments are inadequately presented in our schools. May I say, however, that I am just a trifle

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[1] Conant, James B., *On Understanding Science: An Historical Approach.* New Haven: Yale University Press, 1947. This volume is also available in the paperbound, 35-cent Mentor Book edition of the New American Library of World Literature, New York.

> uneasy when you state that "the field of science and technology is one of the most neglected areas in the entire *social studies*." While I suspect that you mean that the area of applied science and the technological implications for society are sadly neglected, I am sure you do not mean that the process of travail by which scientific knowledge is created initially is properly part of the "social studies" program.

This letter is quoted at some length for the simple reason that the thing the science educator is "sure" was *not* meant is precisely the thing which is of most concern. Neither social studies teachers nor any other teachers should be content merely to describe what applied science and technology are doing *for* teachers; they must also raise the crucial question of what science and technology are doing *to* teachers. The problem social studies teachers must come to grips with is not merely the social implications of automobiles or egg-beaters, but the social implications of science itself. But one cannot begin to discuss the social implications of science until he has at least a rudimentary understanding of science, which is to say of the scientist, for without scientists we have no science. It follows that the way the scientist works and the "process of travail" by which he creates scientific knowledge needs to be explored and understood by as many people as possible, for until the "process of travail" is explored and understood a lot of otherwise intelligent citizens are going to think of science as modern magic and of the scientist as a twentieth-century magician who needs only to pass his hand over his Aladdin's lamp to reveal the wonders of heaven and earth.

The students Mr. Conant had in mind were college students, and the case studies he advocated were fairly detailed studies of a select group of scientists. Moreover, he was talking about a complete course organized along these lines. Several years after he made the original recommendation, this type of course was tried out at Harvard College. Dr. Conant himself participated in the organization and the teaching of this course. "I find it works tolerably well," he commented.

The only way such a course could be incorporated into the present secondary school curriculum would be through the science teachers. They, themselves, would have to make room for it in their program, and this is something for them to consider. But there are real values to be gained by a much more modest approach. Case studies ranging from the simple to the fairly detailed can be injected into *any* social studies course. Moreover, teachers can begin the "injections" in the early grades in the form of brief stories about scientists and inventors whose achievements are recognizable by even these younger boys and girls. One familiar social studies textbook used in the fourth grade is organized around the central theme of "*what* men have learned and *how* they—and we—have learned what we now know." Each of the units in the book—including units on tools and machines, travel and transportation, communication, and health—contains a series of stories about scientists and inventors and the work they did. In the unit on health, for example, the boys and girls meet Pasteur, Roentgen, Alexander Fleming, and a number of other scientists. The stories the pupils read are a long step from the detailed studies Dr. Conant prescribed for undergraduates in college, but the point is that a beginning can be made, and immediately, in any social studies course at any grade level. And it is imperative to make this beginning, or, if it has been made, to push the matter much further than has yet been done in most social studies courses. As A. N. Whitehead wrote in the concluding paragraph of his classic volume, *Science and the Modern World,*[2] in which he traces the origin and the development of modern science:

> The moral of the tale is the power of reason, its decisive influence on the life of humanity. The great conquerors, from Alexander to Caesar, and from Caesar to Napoleon, influenced profoundly the lives of subsequent generations. But the total effect of this influence shrinks to insignificance, if compared to the entire transformation of human habits and human mentality produced by the long line of men of thought from Thales to the present day, men individually powerless, but ultimately the rulers of the world.

Whether the start is in the early grades or in the upper years of the secondary school, however, emphasis should be upon the scientist himself and the "process of travail" by which the scientist arrives at his conclusions. Conant wrote:

> I cannot emphasize too often, that the course in question must *not* be concerned with the fruits of scientific inquiries, either as embodied in scientific laws or theories or cosmologies, or in the applications of science to industry or agriculture or medicine. Rather, the instructor should center his attention on the ways in which these fruits have been attained. One might call it a course in "scientific method" as illustrated by examples from history, except that I am reluctant to use this ambiguous phrase. I should prefer to speak of the method by which science has been advanced, or perhaps we should say knowledge has been advanced, harking back to Francis Bacon's famous phrase, "The Advancement of Learning."

A Sample Case Study

It might be helpful at this point to examine one of the "case histories" Dr. Conant presented to demonstrate his proposition. Take for this purpose the discovery of the electric battery. In this story, here briefly summarized, two scientists are at work in the late eighteenth century. Dr. Conant points out:

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[2] First published in 1925 by the Macmillan Company, and now available in the 35¢ Mentor Book edition of the New American Library of World Literature.

> This case history illustrates the fact that an accidental discovery may lead by a series of experiments (which must be well planned) to a new technique or a new concept or both; it also shows that in the exploration of a new phenomenon the experiments may be well planned without any "working hypothesis" as to the nature of the phenomenon, but that shortly an explanation is sure to arise. A new conceptual scheme will be evolved. This may be on a grand scale and have wide applicability, or may be strictly limited to the phenomenon in question. A test of the new concept or group of concepts in either instance will probably lead to new discoveries and the eventual establishment, modification, or overthrow of the conceptual scheme in question.

Sometime before 1786, Luigi Galvani, an Italian physician and a professor at the University of Bologna, while working in his laboratory, was interrupted by one of his associates. But let Galvani report the incident in his own words:

> I had dissected and prepared a frog . . . and while I was attending to something else, I laid it on a table on which stood an electrical machine at some distance. . . . Now when one of the persons who were present touched accidentally and lightly the inner crural nerves of the frog with the point of a scalpel all the muscles of the legs seemed to contract again and again. . . . Another one who was there, who was helping us in electrical researches, thought that he had noticed that the action was excited when a spark was discharged from the conductor of the machine. Being astonished by this new phenomenon he called my attention to it, who at that time had something else in mind and was deep in thought. Whereupon I was inflamed with an incredible zeal and eagerness to test the same and to bring to light what was concealed in it.

Now there are three extremely important observations that need to be made at this point. First, the discovery was purely accidental. Second, although Galvani "had something else in mind and was deep in thought," he was not annoyed at the interruption. On the contrary, being confronted with a new and puzzling phenomenon, he "was inflamed with an incredible zeal" to find an explanation. As Pasteur once observed, "chance favors only the prepared mind." Galvani, a true scientist, had developed just such a "prepared mind." Third, and by no means least important, Galvani followed up his initial observations with one well-planned experiment after another.

In the course of his experiments, Galvani soon demonstrated that there was a direct and causal relationship between the sparking of the electrostatic machine and the twitching of the frog's legs. "Without fail," he noted, "there occurred lively contractions . . . at the same instant as that in which the spark jumped. . . ." This happened, however, only when the experimenter touched the frog's legs with the metallic blade of the scalpel which he held in his hand. In brief, as Conant explains, Galvani demonstrated that "the nerves and muscles of the frog's leg constituted a sensitive detector of an electric charge."

And then Galvani was suddenly confronted by one of those bewildering situations which from time to time are thrust at every scientist working on the frontiers of knowledge. In the course of his experiments, he found that he did not need the electrostatic machine to make the frog's legs twitch. He discovered that if the leg and nerves were connected by *two different* metals, the frog generated its own electricity and the muscles contracted.

Are there any conclusions to be drawn from all this detail that will have meaning for social studies students in mid-twentieth century? The answer is that the conclusions are there *if* social studies students' primary concern is with the manner in which Galvani, the scientist, worked and "the process of travail" he went through as he sought to discover new truths. In the first place, it should be stressed that Galvani, starting with an *accidental discovery* had, through a series of controlled experiments, arrived at the principle of the electric battery—*without even suspecting what he had accomplished.* He had recorded the significant facts, but from those facts he had formulated a working hypothesis, or conceptual scheme, that actually led him away from, rather than toward, the idea of an electric battery. The experiments, he concluded, "cause us to think that possibly the electricity was present in the animal itself."[3]

It remained for Alessandro Volta of Padua to draw the conclusion Galvani failed to draw. Volta began by working, as Galvani had done, with the problem of "animal electricity." But Volta had at hand a new instrument he had invented, "a sensitive condensing electrometer" with which he could detect small charges of electricity. In the course of *his* experiments, Volta found that he did not need the frog at all; almost any moist material would serve just as well. He demonstrated that electricity could be produced by separating two different metals in water containing lye or salt. Reporting his discovery in 1800 in a letter to the President of the Royal Society of London, Volta wrote:

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[3] As Conant reminds us, any reader "can perform the equivalent of Galvani's experiment. A copper coin and a silver coin placed above and below the tongue when touched together produce in the tongue a peculiar 'taste.' A very small electric current flows and our tongue records the fact through a series of interactions of electricity and nerves much in the same way as did Galvani's 'prepared frogs.'" (Incidentally, it might be well to remind the students that the coins should first be sterilized!)

> Thirty, 40, 60 or more pieces of copper, or rather of silver, each in contact with a piece of tin, or of zinc, which is much better, and as many layers of water or of some other liquid which is a better conductor than pure water, such as salt-water or lye and so forth, or pieces of pasteboard or of leather, etc. well soaked with these liquids; . . . such an alternative series of these three sorts of conductors always in the same order, constitutes my new instrument; which imitates . . . the effects of Leyden jars. . . .

Volta had "invented" the electric battery, the first source of continuous current. Such, in summary fashion, is the "case history" of the early steps in the development of one of mankind's truly fruitful inventions. These steps included:

1. An accidental discovery
2. A series of controlled experiments
3. The formulation of a working hypothesis to explain the facts ("animal electricity")
4. More controlled experiments by another experimenter (Volta)
5. The formulation of an entirely different hypothesis *and* the development of an entirely new conceptual scheme into which the facts about electric batteries neatly fit.

The original problem under investigation was "animal electricity." "This has now become largely a meaningless question," Conant observed, "but in attempting to find an answer Volta discovered the electric battery. Such is often the course of scientific history. We end by solving a problem other than the one first at issue."

Before leaving this matter of "case histories," two final observations are in order. In the first place, the outline of this particular study with the running commentary as to some of the conclusions that need to be drawn from it tend to make what is essentially a fairly uninvolved story appear much too complex for a brief lesson in the average social studies classroom. Appearances to the contrary, this is not true. Given the simple, straightforward running account of what Galvani and Volta did, most juniors and seniors in high school would be able to draw their own conclusions, and in the process move closer to an understanding of how a scientist works.

In the second place, Conant offered the Galvani-Volta "case history," and we summarized it, not because it is an exceptionally significant one but, rather, because it provides a reasonably simple illustration of the kind of material that can be presented in the classroom. Conant himself gave several other examples, and the opportunities for a resourceful teacher to develop his own file of stories, or "case histories," are literally almost endless. Here, it would seem, is an extremely fruitful field for social studies teachers and science teachers to explore together.

THE SPIRIT OF SCIENCE

Return now to Dr. Conant's concern over the layman's enthusiasm for the products of applied science and the layman's almost utter indifference to the meaning of science itself. Conant is not by any means the only scientist to express concern over this problem. J. W. N. Sullivan wrote in his *The Limitations of Science*:

> If we are to judge from what seems the overwhelming evidence provided by such activities as politics, business, finance, we must conclude that the attention and respect accorded to science is directed wholly to its results, and that its spirit is the most unpopular thing in the modern world. *Yet it could very reasonably be claimed that it is in its spirit that the chief value of science resides* [our italics]. This can be asserted without abating anything of our claim for the value of its results.[4]

The "spirit" of science is the spirit of freedom. Anyone, young or old, who has the opportunity to look at the manner in which the scientist goes about his business quickly realizes that the scientist must be free to follow his investigations wherever they may lead him. But it is also obvious that this freedom imposes a heavy responsibility on the scientist, the responsibility for handling the facts and reporting his findings as accurately and as faithfully as is humanly possible. However the scientist may behave at home or at a cocktail party or when he is discussing political or economic or social problems with his friends, the moment he enters his laboratory he must divest himself of all prejudices and vanity. He must, in his role of scientist, act with complete integrity. If he lowers his standards, he betrays himself as a scientist and he betrays his fellow scientists who depend upon him even as he depends upon them to be accurate and impartial.

Now, the interesting thing is that scientists did not always appreciate and maintain their present high standard of objectivity. This requirement was something they had to learn; indeed, it was in the process of learning that an impartial examination of facts is essential for all scientific investigation that men created, or "invented," modern science. To quote Conant again:

> If I read the history of science in the seventeenth and eighteenth centuries rightly, it was only gradually that there evolved the idea that a scientific investigator must impose on himself a rigorous self-discipline the moment he enters his laboratory. As each new generation saw how the prejudice and vanity of their predecessors proved stumbling blocks to progress, standards of exactness and impartiality were raised. . . .

Man begins to see science in its proper perspective when he becomes aware that modern science did not spring full grown into the world. On the contrary, modern science is the product of the same trial and error, and the same endless struggles which have characterized all of man's achievements, including the development of the way of life we call democracy. The "spirit" of modern science—scorn of prejudice; respect for impartiality; devotion to the processes of critical thinking, and the determination to refine those processes; intellectual curiosity; and, above everything else, the quest for beauty and truth—this "spirit" existed in society long before modern science was born. If the physical sciences have sprung from these roots, so, too, have the social sciences and, most significant of all, the institutions and practices of democracy. In this large and general sense, science and democracy are blood brothers.

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[4] Sullivan, J. W. N. *The Limitations of Science.* (New York: The Viking Press, 1933. Also available as a 35-cent Mentor Book of the New American Library of World Literature, New York.

The men who created, or developed, modern science had *to learn* to step into the laboratory with an open mind. They had *to learn* to accept the fact that all the "truths" they revealed were at best provisional "truths." They had *to learn* that without an endless striving for impartiality and the utmost in accuracy, there can be no science and the search for knowledge and understanding becomes a mockery. Modern science has borne rich fruits because scientists learned these lessons, and learned them well.

Democracy will bear even richer fruits when more of us, scientists and laymen alike, make a greater effort than we have yet done to tackle our everyday problems, large and small, *in the same spirit* with which scientists tackle the problems they meet in the laboratory. Even a single class discussion based upon a brief case study of a simple experiment in science may do more to instill respect for the basic values of democracy than a score of class periods devoted to glittering generalities about "freedom."

OTHER LESSONS FROM SCIENCE

If the discussion up to this point inadvertently placed the scientist on a pedestal, let's get him down from this position as quickly as possible. He doesn't belong there. A fairly widespread view to the contrary, the scientist is a man, not a magician.

Take the matter of "the scientific method." Now the "scientific method" seems beautifully clear when we read in a textbook about the hypothetical scientist and the precision with which he tackles a problem and proceeds step-by-step to the solution. Only it isn't that way at all, and a few relatively simple case studies will quickly reveal this fact. Whitehead once referred to "the state of imaginative muddled suspense which precedes successful inductive generalization," and as we observed earlier, Conant called the "scientific method" an "ambiguous phrase." Conant later amplified this statement by calling attention to "the stumbling way in which even the ablest of the early scientists had to fight through thickets of erroneous observations, misleading generalizations, inadequate formulations, and unconscious prejudice. . . ." This, he went on to say, "is the story which [it] seems to me needs telling." The layman should understand that the scientist is infinitely patient, that he is incredibly painstaking in his efforts to make precise measurements, that he sets up the most elaborate safeguards to protect himself from erroneous conclusions. But the layman should also understand that chance, the informed guess, the accidental discovery (remember Galvani!) also figure large in the daily life of the scientist, even as they figure large in the daily lives of all men everywhere. In brief, and to repeat, we are dealing with men, not magicians, and this is important to understand, if only because it will help to prevent man from following false gods.

It may be worth noting in passing that the scientist records no "failure." An experiment that leads him down a blind alley becomes merely another bit of data upon which another scientist can build. Here is another lesson everyone can profitably learn and apply to his own everyday problems.

The foregoing discussion has skirted the subject of the limitations of science, but it would be well to take a hard and direct look, if only a brief look, at one of the most obvious limitations. Science is concerned with what William James once called "stubborn and irreducible facts." The scientist has been successful in his own field because he has worked with facts. Indeed, he cannot work if he does not have measurable data with which to work. So it is that the scientist has been able to provide the basic formulas from which the engineer could construct, for example, the hydrogen bomb. But at this point science and technology cease to function, for neither the scientist nor the engineer have at their command any "scientific" way of developing formulas whereby mankind can live with the hydrogen bomb.

This, too, is an important lesson for all mankind to keep in mind. The liberal arts, the humanities, the fields of human endeavor that encompass matters of mind and of spirit, these, too, are essential in the scheme of things, and if man neglects them science itself becomes meaningless and man may disappear from the face of the earth in a final tragic holocaust.

The Larger Perspective

For mid-twentieth century man, an understanding of science is an essential part of the irreducible minimum of education he requires if he is to function effectively as an individual and as a citizen. The blind cannot lead the blind, and the social studies teacher who accepts his share of the responsibility for developing this understanding will readily admit that there are large gaps in his own education that need be filled as quickly as possible.

Although there are many books to which a teacher can turn for the story of the development of science, this author's first recommendation is the volume cited earlier, A. N. Whitehead's *Science and the Modern World*. Chapter 1, "The Origins of Modern Science," is especially valuable for the reader who wants to gain a larger perspective on the subject of science. In this chapter, Whitehead outlines the development of science from the days of ancient Greece to the present. His is not a history of science, nor even an outline of the history of science, but, rather, a penetrating analysis of how *and* why modern science has developed, and what it has to offer twentieth-century man, and what its limitations are. If there exists a more brilliant analysis of the subject, this author has not seen it.

Two of the points Whitehead makes are that science is "a mode of thought" and that science has a "universal" character. A word about each of these observations is in order. Whitehead states:

> . . . this quiet growth of science has practically recoloured our mentality so that modes of thought which in former times were exceptional are now broadly spread through the educated world. . . . The new mentality is more important even than the new science, and the new technology. . . . This new tinge to modern minds is a vehement and passionate interest in the relation of general principles to irreducible and stubborn facts. . . . It is this union of passionate interest in the detailed facts with equal devotion to abstract generalization which forms the novelty in our present society. . . .

Anyone who doubts the extent to which he is concerned during most of his waking hours with "irreducible and stubborn facts" should spend a quiet hour thinking upon the matter. We regulate our lives by the clock, having transformed time to the measurable data of hours and minutes and seconds.[5] Man measures learning (or pretends to measure it) by numerical grades. He invokes the "scientific method," or what he chooses to call the "scientific method," in most instances in which he earnestly and sincerely seeks an answer to his problems. And there is nothing wrong with all this, for life has become immeasurably more comfortable since man has devoted himself to the "irreducible and stubborn facts." But, as Whitehead points out, our present "mode of thought" is not the only possible "mode of thought," and the ways of science are not the only ways of discovering truth. He pointedly warns:

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[5] In his well-known essay, "The Monastery and the Clock," Lewis Mumford notes that "the bells of the clock tower almost defined urban existence. Time-keeping passed into time-serving, and time-accounting and time-rationing. As this took place, Eternity ceased gradually to serve as the measure and focus of human actions." Readers who are not familiar with this essay will find it perhaps most readily in Mumford, Lewis, *The Human Prospect*. Boston: The Beacon Press, 1955.

> There is a Nemesis which waits upon those who deliberately avoid avenues of knowledge. Oliver Cromwell's cry echoes down the ages, "My brethren, by the bowels of Christ I beseech you, bethink that you may be mistaken."

Science is not the whole of life, or even the most important part of life. Here, then, is another lesson we need to learn—and teach.

The second observation of Whitehead's is his emphasis upon the universality of science:

> Modern science was born in Europe, but its home is the whole world. More and more it is becoming evident that what the West can most readily give to the East is its science and its scientific outlook. This is transferable from country to country and from race to race, wherever there is a rational society.

The fact that science provides a common meeting ground for men of every nation, race, and creed gives reason for hope for the future. But man needs, at the same time, to guard against what Whitehead calls the dangerous "Gospel of Uniformity":

> Mankind has wandered from the trees to the plains, from the plains to the seacoast, from climate to climate, from continent to continent, and from habit of life to habit of life. When man ceases to wander, he will cease to ascend in the scale of being. Physical wandering is still important, but greater still is the power of man's spiritual adventures—adventures of thought, adventures of passionate feeling, adventures of aesthetic experience. A diversification among human communities is essential for the provision of the incentive and material for the Odyssey of the human spirit. Other nations of different habits are not enemies: they are godsends. Men require of their neighbours something sufficiently akin to be understood, something sufficiently different to provoke attention, and something great enough to command admiration. We must not expect, however, all the virtues. We should even be satisfied if there is something odd enough to be interesting.

SUMMARY

These, then, are a few of the lessons social studies teachers need to teach about science. All of these lessons require social studies teachers to look at science through the eyes of the historian, or, more accurately, through the eyes of the philosopher-historian who is not irrevocably committed solely to the study of "irreducible and stubborn facts." The last thing we want, and should make every effort to avoid, is a survey of the history of science. One of the things needed if teachers are to help youngsters reach out for an understanding of the world in which they live, is a careful look at a selected and chronologically arranged group of case studies, picturing scientists or technologists at work. The object is to reveal the values in science, the role science and technology are playing in the development of the world around us, and, perhaps most important of all, the limitations of science.

CHAPTER III

Using Science and Technology To Improve Living Conditions in Underdeveloped Countries

Howard H. Cummings

Since 1945 two different aspects of science have influenced the public mind whenever it turned to problems of international relations. The first aspect is the threat of total destruction which has grown with each successive test of thermonuclear weapons. Sometimes the lesson has been sudden and overwhelming as the bomb explosion at Hiroshima, the announcement that Russia had an atomic bomb, or the test on the first hydrogen bomb. At other times the realization has come more slowly and news has leaked of the threat of the radioactive fall-out which covered large areas following the explosions. Throughout history international peace and security from the destruction of war has seemed highly desirable. Each successive event since August 1945 has emphasized the truth that it has now become imperative.

But science holds out a promise for increasing human welfare and happiness as great as the threat it has spread over the prospect of man's future existence. Poverty, hunger, and disease have worked in a vicious downward spiral throughout history to cause human misery and degradation. There is now the prospect that science will introduce a new spiral into the lives of people, particularly in undeveloped countries. The new spiral will be improved health, improved nutrition which will lead to greater productivity, and this in turn will lead to even better health and more food which will again increase productivity. On the new spiral, guided by science, people will ascend toward health and plenty where the old spiral carried them downward toward sickness and want. Famine and pestilence, like war, take their tolls of human lives. There is the hope that science might eliminate war by convincing men that all-out warfare would be totally destructive. There is also hope that science may prolong human life and increase human happiness in countries still characterized by poverty, hunger and disease.

Two international organizations are already in existence to work for improvement on a world scale in these spiral areas. The Food and Agricultural Organization (FAO) was formed on October

16, 1945, and the World Health Organization became a permanent body on September 1, 1948. In August 1955 a conference was held at Geneva under the United Nations on the peaceful use of atomic energy. This conference may mark the beginning of another great international effort to use science for human advancement by increasing the sources of energy.

The efforts of international organization do not include all of the programs for bringing the gains of science and technology to the people who live in underdeveloped countries. The Point Four Program of the United States outlined by President Truman in his inaugural address of January 20, 1949 launched a broad and continuing program of technical assistance. A year later in January 1950 the Colombo Plan was launched in the countries of South and Southeast Asia to improve living conditions in this region.

The new feature in all these programs was that nations committed themselves to help other nations, either through international bodies or directly. President Truman expressed as a national aim, "that we should make available to peace-loving peoples the benefits of our store of technical knowledge in order to help them realize their aspirations for a better life." The idea that people who had developed science and technology in their own countries had some obligation to the people in the underdeveloped countries who suffered from hunger and preventable disease was not new. Albert Schweitzer has become a personal symbol of the most humanitarian expression of this ideal. Much of the missionary activity of religious groups has been directed to these ends. The work of the Rockefeller Foundation over the years in carrying scientific knowledge and know-how to the people in underdeveloped countries has now been told by Raymond B. Fosdick, formerly the president of this foundation.[1] Various factors have operated to step up the tempo, bring greater emphasis to the problems, and allocate more money and personnel to work upon them. One of these problems is the growing "One World" feeling which has developed in the technologically advanced countries. Another is growing awareness in the underdeveloped countries of the benefits which have come to their more scientifically developed world neighbors, and a desire to share these benefits.

Following the general scheme of Part II of this Yearbook, the problem will be discussed here in the same areas which make up the chapters of Part II, namely agriculture, health, and the promise of atomic energy for future technological development.

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[1] Raymond B. Fosdick. *The Story of the Rockefeller Foundation.* New York: Harper and Brothers.

FOOD

The farmer plants five seeds says the old adage, one for the bug, one for the crow, one to rot, and two to grow. The total world losses to insects is estimated at $4 billion. Plant diseases destroy an additional $3 billion worth of food. Better seeds, better insect control, better control of plant diseases will add to the world's food supply. In most countries of the world the people rely on a basic crop for the main part of their sustenance. Rice in Asia, corn in Mexico, wheat, rye, and barley in many countries, potatoes in a few. Americans eat milk, eggs, and meat, but this is an expensive way to live. If a human being eats corn directly he gets seven times as much nourishment from a bushel of corn than he would get if he fed the corn to a pig and then ate the pig. This simple bit of arithmetic explains why most people live mostly on grain with a little meat, eggs, and milk added rather than mostly on animal products with a little bread and potatoes. It would take about seven times as much arable land to feed the people in some of the underdeveloped countries if they departed from a basic cereal diet.

One of the first problems in most of the underdeveloped countries of the world is to increase the yield of grain. The first goal of the Colombo Plan for Southeast Asia was to increase rice production. In the Eastern Mediterranean area an effort is being made to increase the production of wheat and barley. In other countries a larger yield of corn is needed.

One way to increase the yield is to introduce new varieties of plants. Hybrid corn, already in general use in the United States, increases the corn yield by 20 percent. Better seeds and testing seeds for germination also increase the yield. The use of chemicals to control known plant diseases and insect pests cut down losses. The use of the aeroplane to spray large areas adds to the effectiveness of insect and disease control by chemicals. One of the most widely reported projects is the work on locust control in the Arab lands of the Eastern Mediterranean. Since scientific agriculture must start from scratch in many underdeveloped countries the early achievements may be large. Later achievements may be harder and the problem of maintaining early gains depends on the continued use of the new varieties, continued seed testing and keeping up the never-ending fights against plant diseases and insects.

The efforts to increase the yield of meat, dairy, and poultry products follows a similar pattern, namely improving the quality of the stock and combatting diseases. Since most of the livestock of the world was developed in the temperate zone, one of the problems is to develop breeds that can live and thrive in the tropics. Culling poultry flocks to get better egg production and improving dairy herds to get more milk production are other projects now being carried forward. The production of calves by artificial insemination makes this task easier and less expensive.

Animal diseases take their toll of livestock and cut down the food supply. In 1956, 5000 cattle were exported from Ethiopia, a nation formerly under quarantine because of rinderpest. Rinderpest and foot and mouth disease are well-publicized cattle diseases which have received attention for a long time. There are poultry diseases, diseases that afflict sheep, and others where additional research must be carried on before any control measures beyond quarantine can be effective. All measures work in the direction of increasing the world's food supply by building a profitable livestock industry in tropical countries.

Closely related to livestock production is the problem of improving grazing or forage lands by new or improved grasses.

The problem of water and water use in agriculture is receiving a great deal of study and exploration. Many new irrigation projects are being built in many parts of the world. In some regions only a little irrigation is needed—if enough water can be impounded to flood the rice paddies one time a crop is insured. In other regions irrigation has raised new problems. Tropical land loses its nitrogen quickly and a yield of 40 bushels of rice per acre dwindles to 10 after a few years of cultivation. Some system of crop rotation is needed to supplement irrigation for a continuous yield.

Arid lands make up one-fourth of the earth's surface. If more water can be provided by impounding water during the rainy season, finding ground water by surveys and digging wells, and by seeding clouds near the sea coast, the food supply can be increased. In 1955 a meeting of 500 scientists from 28 countries was held at Albuquerque, New Mexico. At this meeting many new techniques were discussed and research projects prepared with the aim of increasing the food supply by bringing arid land into production.

In other parts of the world the problem is too much water. Here drainage projects, flood control, the control of erosion, and the process of leaching where nutrients are carried deep into the soil are the problems which challenge scientists and engineers who are working to add land with too much rainfall to the food producing acreage of the world.

Farm mechanization is a difficult problem in many underdeveloped countries. In the United States, labor is scarce and capital is plentiful. The tractor, the mechanical cotton picker, the cornhuskers, and the combine thresher have greatly increased the number of acres that one man can farm. In underdeveloped countries, labor is often plentiful but capital is scarce. Better plows, reapers, and threshers rather than American machinery are tools better adapted to an agricultural society with little education and limited technical knowledge.

A final problem where both health and agriculture are involved is nutrition. Many people in starch eating countries suffer from protein malnutrition. A balanced diet depends on the supply of food available, methods of processing, preserving, and storing food, and on the eating habits of the people. Nutritionists and home economists must supplement the work of agronomists, botanists, chemists, engineers, and agriculturists if the people in underdeveloped countries are to be well nourished.

Since farming depends on the weather, meteorology is needed in underdeveloped countries along with the weather predictions American farmers use. In Pakistan the development of this service is now a major project. Soil surveys must be made to determine the potential productivity of various soils for varied crops. Agricultural experiment stations must be established to keep up continuous research needed to test out and adapt new agricultural discoveries in a country where the climate, soil, rainfall, and general flora and fauna are different. Few scientific problems are ever finally solved and the scientists will have to be prepared to work continually on the problem of a food supply for their people.

A vigorous debate has been carried on in recent years over the future of the human food supply. One group of writers has predicted an economy of abundance for a larger population. A second group has taken a more somber view of a growing population becoming increasingly hungrier on a planet already "plundered." Prediction is an uncertain business even for the scientist and the statistician. During 1955 and 1956 the world supply of food increased faster than the world population. This was a reversal of a long trend but there was one shadow on an otherwise cheerful picture—the food supply did not increase greatly in the countries which had a large increase in population and the people of these countries did not have the means to purchase food from abroad. The difficult and controversial problem of population prediction, with the proposals for population control which accompany many of these predictions, must be considered in relation to food as a world problem. The *World Food Survey* published at intervals by the FAO is an attempt to supply basic data for considering such problems as food-population ratio on a world scale.

HEALTH

Disease is closely associated with hunger as a challenge to scientists. One aspect of disease which calls for international action is the control of epidemics. This problem has grown as international travel and international trade have increased. One of the responsibilities of the WHO is to make a continuous study of the incidence of epidemic diseases, report any spread of these diseases, and help organize the national health services for epidemic control. One of the most serious of the epidemic diseases is influenza in its various forms. The historic plagues of typhus, smallpox, typhoid, yellow fever, and others have been brought under some measure of control but continuous programs of vaccination, inoculation, mosquito eradication, and rat control are required to protect the public health from their recurrences. Science keeps the battle against epidemics won only by an ever increasing and highly intelligent warfare.

A second phase of the war on disease is to stamp out diseases in all countries, particularly those diseases whose causes are understood and for which effective and often inexpensive preventive measures and treatment are at hand. In 1909 the Rockefeller Foundation made the dramatic campaign to eradicate hookworm in 11 southern states. Tens of thousands were restored to health, and the world was given a lesson in how to put existing scientific medical knowledge to work. The hookworm demonstration had been preceded by the yellow fever control in Cuba and Panama. The possibility of eliminating diseases by widespread and consistently practiced public health measures has been followed in many countries during the last half-century.

The task is a large one. Each year 3 billion people in the world suffer from malaria and 1 out of 100 of these die of the disease. Mosquito control and medication can reduce both the number of cases and the deaths. The whole tropical world is subject to the disease, and projects for its control are being carried out in most countries in the tropics. Each year 5 million people die of tuberculosis. The WHO has projects for reducing this disease in Turkey, India, China, and Greece. Yaws afflict many people in Haiti and Thailand where control measures are now being carried out. So far the spirochetes responsible for yaws and syphilis have shown no signs of developing a resistance to penicillin which has been used at a relatively low cost per patient to treat 10 million people.

There is a certain danger in reaching conclusions about the future of world health from reading news accounts of the programs made in the field of preventable disease. The world citizen may conclude that all illness can be cured with 75¢ worth of penicillin per head or by dusting jungle brush with DDT or covering a swamp with a film of oil. It isn't that simple even in the preventable disease field. Good health in a country depends on many factors, the first of which is a trained medical service of doctors, nurses, sanitary engineers, and medical technicians. Mothers must receive prenatal care, babies must be delivered, many illnesses require surgery. There are always the diseases for which no cure has been found and others like polio where the preventive vaccine has only recently been discovered. The tropics furnish their full quota of unique diseases which make tropical medicine a field of specialization. Schools of medicine with resources for carrying on medical research are essential. Nurses and health teachers must be trained. Schools of pharmacy and in many countries a pharmaceutical industry must be established. Technical commissions from the WHO and other countries can show communities and nations how to solve some health problems and how to undertake the work required for solving others. But finally the work will have to be organized, the personnel trained, and the resources found for continuing the programs with national funds.

There are many ramifications to the health problem. The importance of nutrition has already been noted. The WHO is also concerned with the hygiene of food handling and community sanitation especially in eating places. A program of public health education is necessary for teaching many of the habits needed for a healthy community.

But the WHO is not concerned only with the physical health of the world's population. It defines health as not the absence of illness, but as a state of complete physical, mental, and social well-being. Psychiatry, psychology, and sociology have roles to play in maintaining mental and social as well as physical health.

As in the case of agriculture, world statistics are necessary for thinking about health problems in world terms. The WHO maintains such statistics. In addition, standards are needed and in this field the WHO has established standards for many of the drugs used in medical practice.

Many scientists and engineers who have worked in underdeveloped countries have come to the conclusion that if science is to be used effectively in the long run the people in those countries must learn to use a great deal of it. Agricultural production, to be maintained, needs commercial fertilizer. To be increased it often requires farm machinery. Better housing and clothing require factories. If some of the conveniences which many people want are to be added to basic necessities, more goods must be produced. A better fed and healthier population may be able to grow this food for their nation and furnish additional manpower for factories—if enough capital can be created to build the factories.

SCIENCE AND EDUCATION

When a country needs industry, particularly heavy industry, to produce goods to improve its standard of living, the question of energy is the first one that must be answered. Does the country have coal, oil, natural gas, or water power to operate the industries it needs? The next question is, Does it have the raw materials to process, particularly metals? Many countries are not certain about exactly what mineral wealth they do have. Geological surveys are being made over large areas for the first time to get some idea of the quality, quantity, and location of the mineral resources. But there is little doubt that in many countries the energy needs will be beyond the resources of the region.

For these countries the international development of atomic energy for peacetime use or some equivalent source of energy is necessary for maximum economic development.

Education at all levels is being increased to help countries understand the use of science and technology. Fundamental education which is education in the fundamentals of better living has been a UNESCO project for many years. Elementary education has been expanded, and in addition to teaching pupils the fundamentals of language and arithmetic the schools are teaching health, nutrition and better farming methods. Books have been written for adult illiterates who are learning to read. Adult education is necessary to make the projects permanent and helps to guarantee the gains made by the elementary schools. If pupils learn to read and are graduated into an adult society which is illiterate, many of them soon lose their reading skills. Motion pictures are used in many countries and the radio is used in some countries to carry a daily lesson in fundamental education to the people. Universal literacy is a necessity in a country which plans to rebuild its economy to include science and technology. Elementary education and adult education, with an emphasis on literacy and fundamental education, are part of the program to achieve better living conditions.

But literacy and fundamental education are not enough. Modern living requires skilled workers. The greatest current educational need in one country is a school for plumbers, because the capital city has just installed a modern system of sewers. Auto and tractor mechanics are needed, machinists, electricians, carpenters, and masons will be required in increasing numbers. One of the most frequent requests received by educators in Europe and the United States is for information about vocational schools and help in getting such schools organized.

In India, the problem is to train top-level technicians and engineers, men who must be trained well above the level of the skilled workers, who are graduated from the vocational schools. India has its universities with scientists engaged in research. It is "knowing-how-to-do" rather than "knowing about" which is the aim of the new technical schools in this country.

In other lands the problem is one of training scholars in universities to work on and seek solutions for the problems which exist in their country. Part of the work will be to make a scientific inventory of natural and human resources of the country.

Educational development is taking place at every level in some one or another of the underdeveloped countries throughout the world today. The range is from an expanded elementary program, where not only literacy but functional education is the aim, to the development of universities where research will be carried on to add to the world's stock of scientific knowledge and to give special attention to the nation's scientific and technological problems. In between are the programs of fundamental education and adult education to change the culture to include a greater use of science. Vocational schools to train skilled workers and technical institutes to train engineers and technicians complete the picture.

An educational system is a part of a nation's culture and few permanent changes in the schools can be made until the culture changes. In some of the countries of the world the culture can be compared to that of Europe in the feudal period. Others resemble Europe in the 18th century. Some are replicas of 19th century Europe. In such countries education either resembles the European pattern of education characteristic of the stage of historical development of the countries or the schools are alien institutions with little influence on the life of the people. It is probably fair to state that as yet no one of the underdeveloped countries has even begun to plan a comprehensive system of education reaching from kindergarten through the graduate school of the university which will include vocational and technical education. The presence of long-standing vested interests joined to hallowed traditions make it safe to predict that a long period of travail will precede the birth of any completely modern system of education.

It is probably safe to say that in this effort to telescope from 50 to 500 years of progress into the short space of a generation of 30 years the services of social scientists are needed as much as those of their colleagues in the physical and biological sciences. In a society where an illiterate chief shares power with an illiterate medicine man over an illiterate population the anthropologist might be as useful as the doctor. In a society where a well-educated and well-mannered aristocracy rules a subject population of illiterate and semi-literate peasants, a sociologist might well begin work with the engineers who are introducing new sources of power to prepare the emergence of a new class of skilled workers, technicians, and engineers. The machine does not work well in a society divided by rigid caste lines. The political scientist will be needed to advise on new aspects of public administration to add to the efficiency of central governments which must assume new duties. Lawyers will be needed to help revise outmoded legal systems. The educator and social psychologist will have to build new attitudes to replace feelings of economic resignation, skepticism about scientific progress, and fatalistic attitudes about life. As long as people continue to believe that they must live as victims of natural forces which science can help them to understand, adapt to and in some measure control, there will be little change of any kind.

The need for the economist has already become clear. Trained people are needed in management and government including statisticians and accountants. Systems of taxation must be devised which will raise revenue to support the new services in health and education. Capital funds must be accumulated for investments in farm and factory. The products of the new industry must find their way into the stream of world trade.

The movement to help the emerging countries to a fuller utilization of science has introduced a new group of ambassadors into the field of international relations. The new emissaries are nurses who are setting up blood banks in underdeveloped countries; the girls who have degrees in home economics, who teach nutrition and better home and family living; the elementary school teachers who have been asked to bring modern methods of education based on a knowledge of child growth and development to the new schools. With the girls go the boys who have finished courses in all the fields of engineering, the graduate of the agricultural college, the veterinarian, the doctor, and the teacher of vocational subjects. While it is probably true that the traditional practitioners in foreign affairs knew too little about science and technology, it is probably also true that the new ambassadors know too little about government, sociology, economics, anthropology, social psychology, geography, and history. An education which could integrate science and social science might be highly useful for all

Americans who are often asked to work on teams composed of different nationalities helping the people in an underdeveloped country to a better way of life.

But the emerging countries have their own contribution to make and perhaps it is they who will finally find a way to integrate the physical and biological sciences with the social sciences. Perhaps in a land where all scholarly disciplines are young, they stand a better chance of growing up together and with each making a contribution to the others worth and usefulness. In the pilot projects social customs and nutrition have to find a common working ground. Economics is learned when tractor pools, cooperatives, and credit unions are formed. Above all is the necessity for avoiding uneconomic activities. If goods can be made cheaply with machines, do not have people make them by hand. A lesson from economic history has taught the leaders to avoid a system of cottage industries which would turn a nation into a huge sweat shop with old people and children working in virtual slavery.

Scientists and technologists who have worked in underdeveloped countries have frequently come home with a greater feeling of humility than they had before leaving home. Some of them have learned a great deal from the job they worked on, and from the people who worked with them. They realize that the people in the emerging countries want to become part of the modern world but hope that they can adapt much of current modernity to their traditional way of life. A second cause for humility is a recognition that the problem on which they worked is one facet of a larger problem which is included in a need for sound economic foundations, increasing productivity, social reconstruction, political stability, broadened world contacts, and a higher level of mass education.

The "One World Concept" is a reality only in the sense that all people inhabit one planet, that the planet is too small an area for nuclear warfare and that the peoples of the world need various products which they must exchange on at least a minimum basis to keep each national economy in operation. At the other end of the scale is the great humanitarian concept of universal brotherhood. Between these concepts is the fact that two out of three people in the world live in underdeveloped countries. Living in such a country means that life expectancy at birth is 35 years instead of 70. It means that per capita income may be $35 a year instead of $1500. It means a short life without the benefits which modern science can supply. As scientists and social scientists from all countries work to spread the benefits of science and human cooperation, the concept of One World will take on more meaning. The emergence of such a new world may bring with it a new race of scholars and professional men knowledgeable in both scientific and social science fields.

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CHAPTER IV

International Geophysical Year

S. Paul Kramer

Despite two major wars, periods of unparalleled economic dislocation, intense national and ideological animosities and rivalries, a noteworthy feature of the 20th century has been the degree of international cooperation. The IGY is an example. "For a period of 18 months, commencing July 1, 1957, more than 5000 scientists from 58 countries will be engaged in a study of man's environment."[1] Notwithstanding the cold war, in the face of tension between the Arab world and others, scientists from the United States and Western Europe as well as from the USSR, Red China, Egypt and other countries will, during the International Geophysical Year, engage in coordinated and synoptic measurements of man's physical environment. These measurements will extend from the South Pole to the North Pole, from the bottoms of the oceans and from the core of the earth to the upper reaches of the atmosphere.

The international origin of this endeavor may be traced back 75 years to the First International Polar Year in 1882-83. At this time intensified polar research on a coordinated international basis was conducted, largely in the Arctic regions. In 1932-33 scientists of 12 countries conducted the Second International Polar Year. It was then anticipated that further polar years would be organized every 50 years from then on.

Subsequently, the rapid development of science combined with the need for basic information, the development of electronic devices for handling this data and the perfection of instruments for gathering environmental data suggested the wisdom of increased and detailed research on man's physical environment.

"Early in 1950 a small group of scientists meeting informally at Washington, D. C., suggested that the Third Polar Year be held 25 years after the second. This group pointed out that the United States and the scientists of the world could not wait until 1982 to replenish their scientific data on man's physical environment. They observed that a period of intense solar activity was predicted for 1957-58 and that this would provide unusually good opportunities for scientists to observe geophysical phenomena in the earth's atmosphere. In the succeeding months the proposal of this small group was brought before several international scientific organizations and was strongly endorsed by all of them."[9]

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[1] Atwood, Wallace W., Jr. *The International Geophysical Year: A Twentieth-Century Achievement in International Cooperation.* Department of State Bulletin 35: 880-86; December 3, 1956.

Thus in October, 1951, the Executive Board of the International Council of Scientific Unions formed a special committee known as the Comité Spécial de l'Année Géophysique Internationale and asked it to plan coordinated geophysical research. Membership in this Committee was drawn from the four international scientific unions concerned with geophysical and related sciences and from the World Meteorological Organization. In 1952 the scope of the undertaking was expanded to include not only the north polar region as was the case with the First and Second Polar Years, but the entire earth. The International Council of Scientific Unions then invited all nations to establish national committees to prepare programs which their countries could carry out as part of an over-all program to be coordinated by the Comité Spécial de l'Année Géophysique Internationale. The United States National Committee for the International Geophysical Year, which was formed by the National Academy of Sciences, is one of these national committees set up at the invitation of the International Council of Scientific Unions.

At various international meetings held since 1953 the United States program was discussed and revised in the light of programs proposed by other countries. Programs of other countries were subject to similar treatment at these meetings. A worldwide program was thus evolved. Participating countries agreed to carry out their investigations in accordance with mutually agreed scientific criteria. All agreed to exchange the data so obtained with all other countries.

The importance of the program stems in large part from the nature of the earth and of the universe which establish our environment. The features [illegible] this environment, particularly those relating to the atmosphere, are caused or affected by the sun, and the events themselves are worldwide in nature. For these reasons better understanding and major advances require a coordinated, worldwide approach.

The worldwide nature of geophysical events is illustrated daily in weather. Storms forming off the east coast of Asia may cause a cold wave to spread over the United States a week later, which may in turn create a new storm in the mid-Atlantic and subsequent floods and avalanches in Europe. Solar flares, erupting from the sun and reaching out 100,000 miles away from its surface, create magnetic disturbances and result in radio communication failures. Such events exert a controlling influence on the daily lives and activities of individuals and affect commerce and industry, the conduct of land, sea and air travel and transportation, and also affect the range and reliability of radio communication and navigation systems.

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[9] *Ibid.*

Early in planning the United States participation in the IGY, the National Academy of Sciences recognized that implementation of the United States program would require federal financial support. It was thus agreed that the Academy would be responsible for developing and carrying out the scientific program and the National Science Foundation, a government institution, would obtain the federal funds needed. As a result of requests by the Foundation, the Congress appropriated $39 million to implement the program.

At the present time the various phases of the United States program are well under way. The rather well-publicized Antarctic phase and the dramatic expeditions into hitherto unexplored areas where observation stations have been set up are familiar. So is the artificial satellite phase of the United States program during which basketball-sized man-made vehicles will be placed in the upper atmosphere, will circumnavigate the planet in about 90 minutes, and will gather geophysical data about outer space. These programs are particularly newsworthy because they represent attempts to reach into hitherto unexplored and difficult areas.

These, however, are but a fraction of the program of study planned by the United States during the 18 months of the IGY. Principal fields of study during the International Geophysical Year are aurora and airglow, cosmic rays, geomagnetism, glaciology, gravity measurements, ionospheric physics, latitude and longitude, meteorology, oceanography, seismology, solar activity, upper atmosphere rocket and satellite studies, and radioactivity of the upper air. The geographical coverage of the United States program includes projects in the United States, the Antarctic, the Arctic, the Equatorial Pacific and the Atlantic and Pacific Oceans. The United States will also cooperate with other countries in projects in the other American republics and in Antarctica.

If the United States program that has been briefly outlined here is considered as but a part of the larger program comprising the coordinated efforts of geophysicists in 58 countries of the world, the International Geophysical Year is in fact a world project. International cooperation on this scale is not an accident; nor has it developed suddenly or spontaneously. Organizations previously in existence such as the International Council of Scientific Unions, the World Meteorological Organization, the United Nations Educational, Scientific and Cultural Organization (UNESCO), the International Relations Division of the National Academy of Sciences itself, have all been operating for many years in the international scientific field and have thus been able to make positive contributions toward the program. Additionally, various governments have been generous not only with money, but also in the field of logistic support. The United States Navy, for example, has made possible the Antarctic program by providing the support necessary for the scientists to perform their work. Similarly in the Arctic, the United States Air Force is providing the necessary logistic support. This list could be expanded.

Members of the United States National Committee for the IGY have been drawn from government, industry, academies and learned institutions devoted entirely to research. The Chairman, Dr. Kaplan, is, for example, Professor of Physics at the University of California. F. W. Reichelderfer, a member of the Committee, is Chief of the United States Weather Bureau. Laurence M. Gould, another member, is President of Carleton College. E. R. Piore, another member, is a Director of Research for the International Business Machines Corp. Merle Tuve is Director of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington.

Neither United States committee members nor project leaders and their associates share common backgrounds. Cultural antecedents, education and training are disparate. All share a general interest in geophysical research but other than this there seems nothing in their past that suggests a program for the educational system as a whole to produce the kind of scientists that are needed for future International Geophysical Years.

Clearly the specific scientific skills that are needed require years of graduate study and/or on-the-job research training. This suggests that the role of the schools in preparing youth for the geophysical sciences is secondary. Although secondary, however, it cannot be dismissed as insignificant. A well-rounded knowledge of the fundamentals of physics is basic to all the disciplines of geophysical research. Such disparate studies as oceanography, seismology, cosmic rays and geomagnetism all require a grounding in the six main branches of physics—heat, light, sound, magnetism, electricity and mechanics. Such thorough groundwork in these principles remains the *sine qua non* of a career in geophysics.

Geophysical research has not progressed to the point where the student can avoid the fundamentals in the interest of specialization. Furthermore, a genuine appreciation of the problems of geophysical research is best served by application of the student to the fundamentals on which it is based rather than more generalized scientific knowledge.

A unique characteristic of geophysical research as distinguished from many other branches of scientific research is its cooperative attributes. As indicated earlier it is no accident that 58 countries are participating in both the planning and execution of IGY's synoptic program. The natural phenomena under observation during the IGY are never merely national in scope. Thus, for example, the northern auroral zone encompasses United States, Soviet, Canadian, Danish, Scandinavian and Finnish territory. Furthermore the phenomena are often so scattered as to preclude their observation by a single scientist in complete personal control of the observing techniques and methods. Unusual solar activity will cause phenomena in the ionosphere over broad areas of the world. Observations of the effects of solar activity will therefore require many scientists in many countries to make simultaneous and coordinated observations.

Such coordination requires considerable advance planning in standardizing observation techniques and methods so that the data gathered is intelligible to different scientists.

Thus, in planning his work, the geophysicist will be benefited by international experience and training. A knowledge of languages and an understanding and comprehension of varying and distinctive national and racial approaches to the problems of scientific inquiry will be helpful. The schools can do much in conditioning youth to an appreciation of the differences in national cultures and outlooks, economic practices and administrative methodology. Sensitivity and awareness of differences is essential to the mature scientist in planning and successfully executing international cooperative research projects. A purpose in outlining in detail the international scope of the International Geophysical Year has been to dramatize the necessity for broad international understanding inherent in the program.

The essential purpose of the IGY is the observation and classification of facts about man's environment. In other words its primary purpose is knowledge as an end in itself. The IGY as an international or national organization is not primarily concerned with the practical applications of this knowledge. These applications will come later and the most significant applications may very well be developed by those in no way connected with IGY research projects.

Concern with knowledge as an end in itself, rather than with its practical applications, is a difficult concept for the primary and secondary school levels. Indeed it is difficult for the mature person. There is continuing pressure on the IGY scientist from the public, the press, and from government to spell out in concrete terms the practical value of his researches. Similar pressure on the teacher from the student is also to be anticipated. Response to this pressure can be made, and explanations can be given of what the results of IGY research may be in terms of everyday life.

The story can be told, for example, of how greater knowledge of deep ocean currents may make the job of the fisherman easier; how more knowledge of the Antarctic could enhance the accuracy of weather forecasting; and how increased knowledge of the ionosphere could improve radio reception and communications.

Stress on the practical, however, as distinguished from the theoretical, is only part of the story. In the long run science is not served by incessant emphasis on the tangible and the practical. Without delicate and wise cultivation by the school of the concept of knowledge as an end in itself world leadership in science could well pass from our hands into others'. Man's insatiable desire for knowledge itself has driven him forward from one discovery to another—discoveries whose practical value was not known nor even considered at the time. This idea is especially difficult for the growing child; yet if it is not preserved, science will not be well served. Perhaps the IGY affords an excellent example of use to the school in presenting and cultivating this important concept.

PART TWO

CHAPTER V

Scientific Research in the United States *and the* National Science Foundation

CLYDE C. HALL

OLD WORLD LEADERSHIP IN CONCEPTUAL SCIENCE

DEVASTATIONS following in the wake of World War II affected the science community no less than other segments of society. Traditionally, Europe and its universities had nurtured fundamental science and conceptual scientists for centuries. But old patterns of life were torn to shreds throughout Europe during and following the war. Science and scientists were uprooted, dispersed throughout the world, and the United States was compelled to readjust its thinking with reference to Europe as the essential center of scientific learning from which relatively young America derived most of its fundamental concepts in science.

Busy cutting through geographic frontiers as new waves of settlers pushed westward; busy allaying the growing pains of a youthful democracy; busy establishing itself among the community of nations, the United States during its colonial period had been compelled by force of time and circumstance to improvise, to innovate, to build furiously, to provide services speedily for its burgeoning population of evacuees from oppressed nations. Little time remained for study, for quiet thought, for conceptual thinking of any kind—except notably, for political thought. It was essentially in the area of political thinking, anyway, that the young colonizers were determined to break from the past. But most of their deep-seated thinking in this area had been done before they arrived in America—it was simply crystallized in the Constitution and the government which grew out of the great minds of Jefferson, Hamilton, Franklin, and their contemporaries. In areas of social and economic endeavor, however, the concepts built upon were largely those inherited from Europe and Great Britain. The colonists entertained no particular desire in these areas to establish new norms of life—the religion of their ancestors, systems of higher education (the public school was an innovation), business and commercial methods, the culture generally of their forebears called for no drastic breakaways of the kind required in politics and government. Thus, they thought not profoundly, but functionally, about their economy and their science, depending heavily on Europe for guidelines.

U. S. TECHNOLOGICAL LEADERSHIP

With each decade of improving stability, the United States acquired growing respect throughout the world, not for the depth of its culture, but for the size and ingenuity of its technological know-how. Nothing seemed too difficult technologically for these brash innovators. Right down to World War II they were gadgeteers for the world, satisfying an insatiable appetite for things material, for things faster, for things more comfortable—for things. Given any supply of fundamental scientific knowledge on which to build, they prepared blueprints from which they produced speedier automobiles and airplanes, bigger television sets, washing machines which dried as well as washed, stoves with the resplendent dials of an airplane instrument panel, refrigerators with deep-freeze compartments, skyscrapers, clothing from chemistry—anything and everything could they apply and develop from the store of scientific knowledge which appeared to be bottomless. Few gave thought to adding to the reservoir of basic knowledge on which they constructed their technological paradise—here and there only was a voice raised, a voice crying in the wonderland of material prosperity. Suddenly, bombs unloaded over Pearl Harbor brought with them an explosive exposé of America's shortcomings in conceptual science.

RESEARCH SPURT OF WORLD WAR II

So recent are these latter-day events that they need little elaboration here. Houses of business and industry, institutions of learning closed their doors, for all very practical purposes, as their manpower was drafted and commissioned, in or out of uniform, to meet the demands of war and relentless antagonists. Backed against a defensive wall, America sought new offensive exits in electronics, in radar, in faster and longer-ranging bombers, more accurate bomb sights. Men and women capable of digging deep into mathematics, physics, chemistry, biology and equally uncompromising disciplines of science were recruited essentially from the universities, traditional centers of fundamental scientific knowledge. Some were found, more were required. Lights burned through the night across the United States as researchers dug far below levels where earlier they had turned up new gadgets to seek now the new scientific knowledge they needed to break through the walls of the enemy's fortress. America researched as never before in its history.

Most dramatic of the researchers, and most portentous for historians, was the team working in utmost secrecy under the west stands of Stagg Field at the University of Chicago in 1942. There, under the direction of Enrico Fermi, Italian born physicist, a team of scientists including Leo Szilard, Walter Zinn, Herbert Anderson, Arthur Compton, Eugene Wigner and others, successfully completed a "chain reaction" for utilizing atomic energy. Later, in describing the series of events which made possible his work, Fermi related times and places of the precedent sequence of discoveries—disclosing our substantial dependence on other-nation knowledges in science. "The story begins in Paris," he wrote, "in 1896 when Antoine Henri Becquerel discovered the existence of radioactive elements." From that point, Fermi noted the successive contributions of Pierre and Marie Curie in Paris; Albert Einstein in Zurich, Switzerland; Ernest Rutherford in England; Bothe in Germany; Joliot-Curie in Paris; James Chadwich in England; Fermi in Rome; and "... the final stepping stone was put in place in Berlin when Otto Hahn, working with Fritz Strassman, discovered fission; it occurred to many scientists that this fact opened the possibility of a form of nuclear (atomic) energy." Soon thereafter came the world-shattering achievement on the historic squash court under the Stagg Field Stadium.

PLANS FOR POSTWAR RESEARCH

Meanwhile President Franklin D. Roosevelt had recognized the significant role that scientific research would play in winning the war. In 1941, he established the Office of Scientific Research and Development under Vannevar Bush, one of America's foremost physicists and engineers, onetime Dean of Engineering at the Massachusetts Institute of Technology, and President of the Carnegie Institution. Seeking to convert for peaceful pursuits the many scientific and technological advances resulting from the great research push of the war, the President, in November 1944, wrote Dr. Bush, saying:

> The information, the techniques and the research experience developed by the Office of Scientific Research and Development and by the thousands of scientists in universities and in private industry, should be used in the days of peace ahead for the improvement of the national health, the creation of new enterprises bringing new jobs, and the betterment of the national standard of living.

He asked Dr. Bush to recommend to him a program of federal action.

SCIENCE—THE ENDLESS FRONTIER

From Vannevar Bush, on July 5, 1945, significantly close to an earlier Independence Day, President Truman received a little book on a day which history may well record as marking the beginning of American independence from other nations for its storehouse of knowledge derived from basic research. Recommended reading for all who would know the sequence of decisive events in United States history is Bush's provocative book: *Science—The Endless Frontier,* a report to the President on a program for postwar scientific research. Substance of the report is captured in the following section from the summary:

> The government should accept new responsibilities for promoting the flow of new scientific knowledge and the development of scientific talent in our youth. These responsibilities are the proper concern of the government, for they vitally affect our health, our jobs, and our national security. It is in keeping also with basic United States policy that the Government should foster the opening of new frontiers and this is the modern way to do it. For many years the government has wisely supported research in the agricultural colleges and the benefits have been great. The time has come when such support should be extended to other fields.
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> The effective discharge of these new responsibilities will require the full attention of some over-all agency devoted to that purpose. There is not now in the permanent governmental structure receiving its funds from Congress an agency adapted to supplementing the support of basic research in the colleges, universities, and research institutes, both in medicine and the natural sciences, adapted to supporting research on new weapons for both Services, or adapted to administering a program of science scholarships and fellowships.
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> Therefore, I recommend that a new agency for these purposes be established. Such an agency should be composed of persons of broad interest and experience, having an understanding of the peculiarities of scientific research and scientific education. It should have stability of funds so that long-range programs may be undertaken. It should recognize that freedom of inquiry must be preserved and should leave internal control of policy, personnel, and the method and scope of research to the institutions in which it is carried on. It should be fully responsible to the President and through him to the Congress for its program.
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> Early action on these recommendations is imperative if this nation is to meet the challenge of science in the crucial years ahead. On the wisdom with which we bring science to bear in the war against disease, in the creation of new industries, and in the strengthening of our Armed Forces depends in large measure our future as a nation.

DEPENDENCE ON EUROPE

Four committees, whose members included many of America's foremost scientists and educators, performed substantial task-force work for Dr. Bush—a Medical Advisory Committee, a Committee on Science and Public Welfare, a Committee on the Discovery and Development of Scientific Talent, and a Committee on Publication of Scientific Information. From the Committee on Science and Public Welfare, under the chairmanship of Isaiah Bowman, President of Johns Hopkins University, came these words of warning:

> . . . Our national pre-eminence in the fields of applied research and technology should not blind us to the truth that, with respect to pure research—the discovery of fundamental new knowledge and basic scientific principles—America has occupied a secondary place. Our spectacular development of the automobile, the airplane, and radio obscures the fact that they were all based on fundamental discoveries made in nineteenth-century Europe. From Europe also came formulation of most of the laws governing the transformation of energy, the physical and chemical structure of matter, the behavior of electricity, light, and magnetism. In recent years the United States has made progress in the field of pure science, but an examination of the relevant statistics suggests that our efforts in the field of applied science have increased much faster so that the proportion of pure to applied research continues to decrease.
>
> Several reasons make it imperative to increase pure research at this stage in our history. First, the intellectual banks of continental Europe, from which we formerly borrowed, have become bankrupt through the ravages of war. No longer can we count upon those sources for fundamental science. Second, in this modern age, more than ever before, pure research is the pacemaker of technological progress. In the nineteenth century, Yankee mechanical ingenuity building upon the basic discoveries of European science, could greatly advance the technical arts. Today the situation is different. Future progress will be most striking in those highly complex fields—electronics, aerodynamics, chemistry—which are based directly upon the foundations of modern science. In the next generation, technological advance and basic scientific discovery will be inseparable; a nation which borrows its basic knowledge will be hopelessly handicapped in the race for innovation. The other world powers, we know, intend to foster scientific research in the future. Moreover, it is part of our democratic creed to affirm the intrinsic cultural and esthetic worth of man's attempt to advance the frontiers of knowledge and understanding. By that same creed the prestige of a nation is enhanced by its contributions—made in a spirit of friendly cooperation and competition—to the world-wide battle against ignorance, want, and disease.
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> The increasing need for the cultivation of science in this country is only too apparent. Are we equipped to meet it? Traditional support from private gifts, from endowment income, from grants by the large foundations, and from appropriations by state legislatures cannot meet the need. Research in the natural sciences and engineering is becoming increasingly costly; and the inflationary impact of the war is likely to heighten the financial burden of university research. The committee has considered whether industry could or should assume most of the burden of support of fundamental research or whether other adequate sources of private assistance are in sight. The answer appears to be in the negative.
>
> The committee has therefore become convinced that an increased measure of federal aid to scientific research is necessary. Means must be found for administering such aid without incurring centralized control or discouraging private support.

Basically this problem is but one example of a series of similar problems of government in a democracy. Many of our important political decisions involve the necessity of balancing irreducible national functions against the free play of individual initiative. It is the belief of this committee that if certain basic safeguards are observed in designing a plan for government support to science, great benefits can be achieved without loss of initiative or freedom.

National Science Foundation Act

Despite the fact that all task-force committees agreed upon the necessity for establishing a federal agency to support basic research in the United States, the proposed agency was long a-borning. Nearly five years intervened between publication of *Science—The Endless Frontier* and establishment by the Congress of the National Science Foundation. Alan T. Waterman, Director of the Foundation, described these uncertain years in an address before the National Association of State Universities, some few months after creation of the Foundation. Dr. Waterman said:

> . . . the President's Scientific Research Board, appointed by the President to survey the interrelations of federal and nonfederal research and development, reaffirmed the Bush recommendation in the following words: "Most of the funds in support of basic research should be expended through a National Science Foundation, responsible to the President. While such support must be part of a broad integrated national program not only for science but for education, there are characteristics of basic research which make the foundation approach particularly desirable in this field."
>
> Hearings on legislation to establish such a Foundation opened in the Senate in October 1945 before a subcommittee of the Committee on Military Affairs. In July 1946 the Science Foundation Bill passed the Senate but died in the House, which was unable to reach it because of the pressure of other legislation. During the first session of the 80th Congress, both Houses of Congress passed a bill which was killed by pocket veto of the President. The President was entirely sympathetic with the general aims and proposals of such a bill but withheld his approval because of certain administrative provisions in the proposed act.
>
> The President gave rather definite expression to his views on the Foundation in his 1950 State of the Union Message. He said: "To take full advantage of the increasing possibilities of nature, we must equip ourselves with increasing knowledge. Government has a responsibility to see that our country maintains its position in the advance of science. As a step towards this end, the Congress should complete action on the measure to create a National Science Foundation."
>
> The Senate again passed a Science Foundation Bill during the second session of the 80th Congress but again the matter failed to receive consideration by the House. Finally, in the second session of the 81st Congress both Houses acted upon a bill which became Public Law 507, The National Science Foundation Act of 1950. It was approved by the President on May 10, 1950. I mention this sequence of events to indicate that the Foundation has finally come

into being not without a long struggle nor without active and vocal argument. It owes its existence not only to the vision and planning of the public-minded and far-seeing men of science and education who first conceived it but in large measure, also, to the persevering efforts and imagination of those members of Congress who persisted in a difficult task until a piece of legislation so vital to our national welfare was finally enacted. The Foundation had a number of friends in both Houses, and I do not wish to leave this subject without paying tribute to the efforts of the House Committee on Interstate and Foreign Commerce, in particular, those of Congressman J. Percy Priest of Tennessee, Congressman Charles A. Wolverton of New Jersey, Congressman Carl Hinshaw of California, Congressman John W. Hesselton of Massachusetts, and Congressman Oren Harris of Arkansas. Full credit should be given, also, to the Honorable Robert Grosser of Ohio, chairman of the Committee.

In the Senate, the Foundation was ably sponsored by Senator Warren G. Magnuson of Washington and Senator H. Alexander Smith of New Jersey. Senators Saltonstall, Fulbright, McMahon, Cordon, and Thye were good friends of the Bill, as were also Senator Kilgore and former Senator Thomas of Utah. In attempting to acknowledge the fine work which has been done on behalf of the legislation, I am aware that I may inadvertently omit the names of others whose work should also be noted. Any such omission is unintentional, and I can only say that the nation owes a debt of gratitude to all who worked to make the National Science Foundation a reality.

. . . For those of you not familiar with the specific terms of the Act I shall quickly enumerate its functions. The Foundation is authorized and directed—

(a) (1) to develop and encourage the pursuit of a national policy for the promotion of basic research and education in the sciences

(2) to initiate and support basic scientific research in the mathematical, physical, medical, biological, engineering, and other sciences, by making contracts or other arrangements (including grants, loans, and other forms of assistance) for the conduct of such basic scientific research and to appraise the impact of research upon industrial development and upon the general welfare

(3) at the request of the Secretary of Defense, to initiate and support specific scientific research activities in connection with matters relating to the national defense by making contracts or other arrangements (including grants, loans, and other forms of assistance) for the conduct of such scientific research

(4) to award, as provided in section 10, scholarships and graduate fellowships in the mathematical, physical, medical, biological, engineering, and other sciences

(5) to foster the interchange of scientific information among scientists in the United States and foreign countries

(6) to evaluate scientific research programs undertaken by agencies of the Federal Government, and to correlate the Foundation's scientific research programs with those undertaken by individuals and by public and private research groups

(7) to establish such special commissions as the Board may from time to time deem necessary for the purposes of this Act; and

(8) to maintain a register of scientific and technical personnel and in other ways provide a central clearinghouse for information covering all scientific

and technical personnel in the United States, including its Territories and possessions.

(b) In exercising the authority and discharging the functions referred to in subsection (a) of this section, it shall be one of the objectives of the Foundation to strengthen basic research and education in the sciences, including independent research by individuals, throughout the United States, including its Territories and possessions, and to avoid undue concentration of such research and education.

You are aware that the Foundation is governed by a Board of 24 members, appointed by the President, and is administered by a Director.

National Science Foundation Organization

Dr. James B. Conant, then President of Harvard University became first chairman of the National Science Board, 24-member governing body of the Foundation, Dr. Waterman is still Director of the Foundation. Speedily, the Foundation organized its programs of support for basic research and education in the sciences. Three major divisions and two offices carry forward the essential work of the Foundation. The three divisions, each headed by an Assistant Director, are: the Division of Mathematical, Physical and Engineering Sciences; the Division of Biological and Medical Sciences; and the Division of Scientific Personnel and Education. Offices are the Office of Scientific Information and the Office of Special Studies. The two first-named divisions are concerned with the support, through grants, of basic research; the other division is concerned with support of education in the sciences through fellowship aid. The Office of Scientific Information is concerned with making the results of research more widely accessible to scientists; the Office of Special Studies is concerned with preparation and analysis of statistical data about amounts and kinds of scientific research pursued in the United States.

Significantly, because its action reflects acceptance of operating policies established by the Foundation, Congress has approximately doubled Foundation appropriations in each of the fiscal years for which the President has presented the Foundation budget. For example, Congress approved a $16 million budget for Foundation operation during fiscal year 1956, and a $40 million budget for fiscal year 1957. Because over the years 80 percent of its budget has been expended for (a) support of basic research in the sciences and (b) support of its fellowship program, let us examine a typical case in each one of these programs.

Research Support

Dr. John Smith, head of the Biochemistry Department of Ohio State University, believes his research into photosynthesis is on the threshold of uncovering new knowledge. He needs $25,000 to continue exploration into the field for another three years. He prepares a proposal, describing the project and its objectives, which he submits to the Foundation through the University. It is accepted by the Foundation, and transmitted immediately to the Program Director for Molecular Biology in the Division of Biological and Medical Sciences. If it meets certain standards, the proposal is sent for review to the Advisory Panel for Molecular Biology—an eight-member group of the nation's foremost biologists who serve as a supporting committee to the Program Director. After careful study by members of the Advisory Committee, the proposal is recommended for approval by the Program Director—if not for the total of $25,000, then for a lesser amount which can be defended out of the budget available to the Program Director. If the proposal is approved by the National Science Board, the Director of the Foundation then notifies Dr. Smith that it will be supported. Soon thereafter an initial check is forwarded to underwrite the research project.

Fellowship Support

Similarly, under the fellowship program, let us assume that Henry Brown, a student at the Massachusetts Institute of Technology, wishes to pursue his study of physics into the doctoral area. His record is promising, but his resources are limited. Following an examination and evaluation by the Educational Testing Service, Princeton, New Jersey, and a further evaluation of his record by the National Research Council (NRC committees of outstanding scientists in several disciplines serve as rating panels for the Foundation), Brown's case is forwarded to the Program Director for Fellowships in the Foundation's Division of Scientific Personnel and Education. Six quality rating groups have been established by the NRC committees. All Quality Group I candidates are recommended to the National Science Board to receive fellowship awards, and all Quality Group II candidates are so recommended to the extent funds permit. Having been rated in Group I, and following Board approval, Brown is now notified by the Director of the Foundation that he has been appointed a Fellow of the Foundation. Soon thereafter, he receives his first monthly stipend check—part of an annual total of $1600, since he is a first-year doctoral student. (Larger stipends are available to applicants for intermediate year, final year, post-doctoral and senior post-doctoral fellowships.)

From its inception and through fiscal year 1956, the Foundation supported approximately 2000 principal investigators of basic research in the sciences in some 200 colleges and universities throughout the nation at a total cost of about $24 million. For the same period, the

Foundation named 3600 Fellows, selected from every state in the Union, at a cost of approximately $8.5 million. While these totals are relatively small when compared with research grants extended by the larger private foundations, they represent a very considerable support of *basic* research in the sciences. It should be borne in mind that the essential business of the National Science Foundation is the support of basic research, undergirding the economy and defense of the United States with an indigenous storehouse of scientific knowledge.

What Is Basic Research?

Basic research is research directed toward an increase of knowledge in science without the objective of an immediate practical application.

Applied research is directed toward practical applications of science; *development* is the systematic use of scientific knowledge directed toward producing useful materials, devices, systems, methods, or processes, exclusive of design and production engineering.

Basic research in the sciences, therefore, feeds the reservoir of scientific knowledge which, in turn, satisfies the needs of applied and developmental research required to meet the demands of society. Because the results of basic research are not directed toward a known goal, except additional knowledge, the researcher must not be controlled or dictated to in any way. When the National Science Foundation, its advisory panels of scientists, and its Board, have determined that a particular proposal for basic research holds the promise of significant advancement for scientific knowledge, and has extended a grant to support it, the Foundation exercises no control over the researcher in any degree—and in keeping with Dr. Bush's foregoing admonition ". . . should recognize that freedom of inquiry must be preserved and should leave internal control of policy, personnel, and the method and scope of research to the institutions in which it is carried on."

A sharper concept of the kinds of basic research which the Foundation supports may be derived from the following typical examples:

Radio astronomy, enabling scientists to observe and measure phenomena of outer space, to "see" by means of radio waves what has heretofore not been visible with optical telescopes.

New sources of power, energy from the atom nucleus, supplementing the basic research of the Atomic Energy Commission, and from the sun, each of which, when probed more deeply by research in basic science, may yield better sources of heat and power

Photosynthesis, basic research into the problem of how plants convert the energy of sunlight to food and fuel, out of which may derive vast benefits for mankind

Solid-state research, the mechanical properties of solids, what holds the atoms together in a solid, and the electrical and magnetic properties of solids, high-speed computation, present-day advances in several science disciplines have outdistanced methods of calculation, calling urgently for wider accessibility of the modern, but costly, facilities in high-speed computation

Geochemistry, with its promise of new methods of detecting ore deposits through research in the fluids and solutions of matter during geologic processes

Geophysical research, using the world as an observing laboratory as in the international geophysical year program.

Because none can predict where such promising areas of research may push into the advancing frontier of science, the Foundation supports a comprehensive program of grants for basic research across the science spectrum in the best interests of the nation's storehouse of scientific knowledge, its economic welfare, and defense.

THE MANPOWER OF SCIENCE

Sound scientific research is not produced in a vacuum. Men and women—thoroughly trained men and women—are required to undertake fundamental research in science. The United States today finds itself in short supply of the highly qualified manpower it needs to satisfy the growing research demands of industry and government. On April 3, 1956, President Eisenhower bespoke the concern of his fellowmen for the nation's diminishing supply of scientists by establishing a National Committee for the Development of Scientists and Engineers, comprised of representatives of major citizens organizations to foster the development of more highly qualified technological manpower. The President said at that time:

> It is my hope that the Committee will:
>
> 1. Assist the federal government in identifying the problems associated with the development of more highly qualified scientists and engineers
> 2. Enlist the cooperation of all interested individuals and groups in analyzing the problem and developing programs to deal with it, and to take the lead in coordination of interested organizations outside the Federal Government
> 3. Make available to all interested organizations information on effective ways of overcoming the obstacles to the training of more qualified scientists and engineers
> 4. Publicize the problems and possible solutions in order to stimulate widespread public understanding and support
> 5. Provide me, from time to time, with a report of progress.

The President directed the National Science Foundation to "provide staff services for the Committee and provide leadership to other departments and agencies in carrying forward activities which will contribute to a solution of the problem."

The President's action served to underscore the significance of many

Foundation programs. Basic research in science, almost by definition, requires for its productive performance a very high order of intelligence. Concern for the manpower of science, both today's and tomorrow's, is therefore priority business for the Foundation. How can its modest resources be used most effectively to assure, as much as possible, the continuing development of men and women capable of constructive performance in conceptual science?

GRADUATE STUDENT RESEARCH ASSISTANTS

In addition to its fellowship program, which directly supports the education of men and women into the doctoral levels of science, other Foundation programs, less known but no less effective, help to broaden the science-manpower base. For example, funds in the average Foundation grant support one or two graduate student research assistants. This support enables young men and women, who might not otherwise have the opportunity, to make their own contribution to research, to become trained in ways of research under direction of experienced research leaders, and to continue their formal academic training. This continuing and immediate contribution by the grants program to the nation's pool of highly trained scientific talent is of utmost importance to the nation's future scientific strength. Thus, in addition to contributing to the nation's store of scientific knowledge, the grants program also provides opportunities to an estimated three to four thousand graduate science students to participate as assistants to mature research investigators and to further their academic training.

YOUTH RESPONDS

Tomorrow's graduate students in science will be found in today's secondary-school classrooms across the nation. One of the most effective stimulants to youngsters to pursue science careers is the Science Clubs of America, sponsored by Science Service, a Washington, D.C., institution organized in 1921 to popularize science. The National Science Foundation granted $40,000 to help support Science Clubs of America for the two-year period 1956-57. Some 300,000 boys and girls participate in activities of 15,000 clubs organized in junior and senior high schools in all parts of the United States. Each pursues hobbies, serious research and useful activities in science and each exhibits annually his best work at local science fairs. Secondary school students whose exhibits are judged best are selected to represent their communities at the National Science Fair where, in turn, each is given an opportunity to share in scientific equipment awards and participate in a 3-day scientific adventure. Follow-up studies of these young scientists, selected to attend the National Fair, have developed statistics which show that the vast majority of them go on to college and beyond, having pursued science careers for their life work.

In addressing some 200 young finalists at the National Science Fair, Oklahoma City, in May 1956, Dr. Waterman sharply pointed up the requirement of broad intellectual attainment in research scientists by quoting James R. Killian, Jr., President of the Massachusetts Institute of Technology, as follows:

> Similarly in the basic sciences our most pressing needs are for those scientists who have the imagination and trained creative power to make the discoveries and generate the new concepts which advance science. Quite properly we hear much about the need for basic research and the funds to support it. These needs indeed are great, but greater still is the need for more scientists who have the trained talent, the motivation, and the conceptualizing power to make basic research really basic.
>
> In stressing the need for exceptional talent, I do not minimize the critical shortage of the rank and file of good competent scientists and engineers. Flag officers are not enough to provide a strong scientific attack force, but the really acute shortage is now in the flag-officer group.[1]

"DON'T BECOME TOO ONE-SIDED"

Reflecting the concern of discerning scientists lest upcoming generations of scientists neglect nonscience phases of their cultural development, Dr. Waterman cautioned his youthful audience in these words:

> . . . I would venture a word of admonition—don't permit yourself to become too one-sided. I need not tell this group that science is as deeply embedded in our culture as the humanities. In fact, its early name was natural philosophy. I hope, however, that you will somehow find time to enrich your lives with a knowledge of history, of literature, of art, of music. Those of you who go on to the doctoral degrees in engineering will find your time so thoroughly absorbed that there may be little left for the humanities. Take it, however limited it may be. Happily, you are not living in a country where freedom to choose one's own career is unknown. No one will expect you to know everything, but scientists, I believe, have as much obligation to reach out toward an understanding of the humanities as humanists must understand the great contribution that science has made to the cultural life of mankind. In fact it will take the teamwork of both to solve many of the problems of the future.
>
> You will find, as well, that if you will set aside some hours of learning to the humanities, you will not only enrich your own life but you will be better able to enrich the lives of your fellow man. Today, industry and government seek more men and women for research and development, and particularly for basic research—men and women equipped with the conceptualizing depth required to dig the known out of the unknown, capable of precipitating the

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[1] Excerpt from Dr. Killian's Sigma Xi Address, American Association for the Advancement of Science Meeting, Atlanta, Georgia, December 27, 1955.

"breakthrough" to new knowledge—knowledge important in the research for truth, and knowledge which can lead to direct benefits to mankind.

Dr. Waterman's appeal to youth, and the appeals of his associates in industry and in education, began to produce evidences of success, by mid-1956, toward encouraging youngsters to pursue careers in science. Within the past 12-month period, the American Association for the Advancement of Science was able to report, for the first time in many years, that if its survey of secondary school enrolments, 1953-55, covering 1.15 million students in 39 states and 80 school systems was representative of the nation, "the downward trend in science and mathematics had ceased and enrolments in these courses are increasing at a faster rate than total enrolments."

WHO WILL TEACH YOUNG SCIENTISTS?

Although the response of youth to the needs of the nation for scientists and engineers appeared encouraging, painstaking analysis of the total science manpower problem by the National Science Foundation still leaves unanswered what the Foundation believes to be the "crux" question: Who is going to teach the increasing numbers of youngsters enrolling in science and math courses? Persuaded that this question must be answered promptly, the Foundation is dedicating millions of dollars to its solution. The Congress has affirmed the soundness of Foundation policy in this direction by approving a substantial budget increase for training high school teachers, thereby endorsing one of the most successful of Foundation programs—summer institutions for science teacher training and retraining.

SUMMER INSTITUTES FOR SCIENCE TEACHERS

First of the Foundation-supported summer institutes was conducted in 1953. The program has been continued each year thereafter. Twenty-five summer institutes were supported by the National Science Foundation in 1956. These provided teachers with opportunities to attend courses in the subject matter of science and mathematics designed especially for them and conducted by scientists noted for competence in their fields and skill in presentation. Grants supporting 1956 Summer Institutes provided instructional costs to host institutions as well as stipends and dependency allowances to participating teachers sufficient to defray the cost of attending.

The 1956 Summer Institutes Program included 13 Institutes for High School Teachers, of which four offered training in the sciences, three in the physical sciences, three in radio-biology, and one each in biology, mathematics, and physics. It included seven Institutes for College Teachers, of which two offered training in chemistry, two in nuclear engineering, and one each in botany, mathematics, and the physical sciences. The remaining five Institutes were designed for joint attendance by high school and college teachers and included one for each of the following: astronomy, biology, chemistry, mathematics, and physics.

The training-institutes idea was extended by the Foundation during the academic year, 1956-57, to include two academic-year institutes. Two grants were made in 1956, one to the University of Wisconsin and one to Oklahoma A. and M. College, for the support of Academic Year Institutes for High School Teachers of Science and Mathematics. Both of these Institutes, to be conducted during the academic year 1956-57, will offer special courses for study in science and mathematics planned cooperatively by members of the science, mathematics, and education departments in the host institutions. Work in the courses designed for high school teachers may be applied in partial fulfilment of the requirements for a master's degree. The grants provide for stipends of $3000 to fifty teachers in each Institute and additional allowances for dependents and travel.

Commenting editorially on the subject of graduate credit offered teachers who complete special science courses, the American Association for the Advancement of Science stated in its publication, *Science,* May 1956:

> The summer-institute program of the National Science Foundation, now extended at Wisconsin and Oklahoma A. & M. to include year-long institutes, has made a major contribution in making available content courses for science and mathematics teachers. This is one of the most significant developments in teacher education in the past 20 years.

NOT ENOUGH SCIENCE TEACHERS

Summer institutes for science teachers provide excellent training opportunities for today's secondary school science teachers who are instructed by some of the nation's foremost scientists during the institute period. But the institutes do not add to the total number of science teachers. In fact, the number of students enrolled in courses for teachers of science and mathematics has steadily declined over the past several years. The National Education Association has estimated that the demand for secondary school teachers needed to meet standard teacher-pupil ratios during the next decade could be met satisfactorily if half of all college graduates over that period could be induced to accept teaching jobs in the secondary schools—a highly unlikely possibility. The urgency of the task of providing adequate numbers of well-trained teachers of science courses is recognized by all who do any thinking about the problem. Leaders of industry and their trade associations, professional societies of scientists, the education community and the government, all have developed action programs designed to overcome teacher shortages, emphasizing the importance, primarily, of salary and status. Time only will tell whether the increasing numbers of youngsters enrolling in science and mathematics courses will find able, dedicated teachers waiting for them in their laboratories and classrooms.

MANPOWER INVENTORY AND STATISTICS

Quantities and qualities of scientific manpower become more meaningful, more useful to the nation when actual numbers, locations and characteristics are cataloged and registered. Thus, in keeping with the foregoing Congressional directive, the Foundation maintains an inventory of United States scientists for ready usefulness in time of emergency and, as needed, in normal times. Its National Register of Scientific and Technical Personnel has been assembled, and is kept up to date, through the cooperation of the several great professional societies of scientists representing disciplines of physics, chemistry, mathematics, engineering, and others. From this inventory of the nation's technical potential, the Foundation is enabled to collect, interpret and disseminate information about the training, employment and supply of scientific personnel. Until the Foundation established this science-manpower clearinghouse, there was no central place in the federal government charged with such responsibility. An early objective of the program was to bring together in a "fact book" designed for general use the best of available information on the supply, utilization and training of scientists. This objective was achieved by the publication, in 1955, of *Scientific Personnel Resources,* now widely used throughout scientific, educational and industrial communities.

COMMUNICATING THE RESULTS OF RESEARCH

If basic research in the sciences, and manpower to carry it forward, are given one-two priority on the action agenda of the National Science Foundation, the third item of importance is dissemination of science information. Scientists feel that no piece of research is complete until it is published. The Foundation pushes that axiom to a more constructive conclusion. No piece of research is complete until published and *made accessible to all who are interested.* Essential business, therefore, of the Foundation's Office of Scientific Information is to make as widely available as possible the published results of research, in keeping with the foregoing recommendation of Dr. Bush that "the government should accept new responsibilities for promoting the flow of new scientific knowledge. . . ." Specifically, the objective of the Office of Scientific Information is to ensure that any United States scientist can obtain any item of scientific information he needs no matter where it originates, and to develop improvements in the organization and availability of scientific information on behalf of all United States scientists.

Published results of scientific research are obtainable from several sources, private and public, at home and abroad. Significant scientific research, whether concluded and published in Great Britain, Sweden, Russia, or other nations of the world, is identified, obtained, translated and distributed to interested scientists and through library outlets in the United States. Similarly, significant research from the laboratories of universities, private industry and the federal government, when unclassified, is becoming more and more accessible as it is made increasingly available through programs specifically designed for the purpose by the Office of Scientific Information. Additionally, this Office seeks to open new and to keep open existing channels of communication among scientists through partial support of scientific journals, through more efficient organization processing, storing, retrieving and providing information for rapid search, and through development of systems which make use of high-speed machines designed to speed up the searching process and the translation of scientific information.

SOVIET MANPOWER

The Office of Scientific Information played a major role in making possible the publication, in 1955, of *Soviet Professional Manpower.* Published jointly by the National Academy of Sciences-National Research Council and the National Science Foundation, the book was written by Nicholas DeWitt of the Russian Research Center at Harvard University. It quickly became the definitive source of information about Soviet scientific manpower resources. It pointed up the fact that the Soviet Union is graduating almost twice as many technical specialists in certain fields as the United States—682,000 professionals in the engineering field between 1928 and 1954 as against 480,000 in the United States during roughly the same period. While serving to focus nationwide attention on the capabilities of other nations in science and technology, the book drew attention as well to domestic problems concerned with identifying and training persons with special aptitudes for careers in science and technology.

THE FACTUAL BASE FOR SCIENCE POLICY

Since its establishment, the Foundation has been concerned with problems of national science policy, especially the role of the federal government in support of science. In attempting to carry out this responsibility, it found that most basic data essential to sound planning were not available. The Foundation, therefore, began the painstaking task of accumulating necessary data concerning the national effort in scientific research and development. Industry, education institutions, private foundations and laboratories, and federal agencies supporting research all cooperate in these studies. The studies, largely carried forward by the Office of Special Studies, provide a firm basis for policy recommendations to strengthen the national scientific effort and furnish guidance to define the responsibilities of government in the conduct and support of research.

For example, *Federal Funds for Science,* published annually, provides detailed information on the extent of government-sponsored scientific research and development, and shows important trends in the level and direction of federal expenditures for science.

Recently published, the study on *Science and Engineering in American Industry,* shows that private industry's annual budget for research and development is close to $4 billion—nearly half of which is supported by the federal government.

The Foundation's study, *Scientific Research Expenditures in the Larger Private Foundations,* covering the 77 largest privately endowed foundations, removed guesswork from assumptions about the amount of support such foundations extend for scientific research. The study indicates that the percentage of support from this source for basic scientific research has declined steadily for the years studied—1939, 1946, and 1953.

Similar fact-finding studies, some now published and many nearing completion, will provide a solid base on which the Foundation can build recommendations for future action. These include:

1. Report on organization of the federal government for scientific activities showing the structure of the federal units and functions performed in science
2. Survey of government-university relationships analyzing sources of support for research at colleges and universities and the nature of such research
3. Survey of research by trade associations and similar organizations
4. Survey of research at nonprofit institutes and commercial laboratories

5. Survey of research supported by selected state governments
6. Survey of the financial support of graduate students and federal stipends to undergraduate and graduate students in the sciences
7. Survey of federal scientific manpower
8. History of science in the federal government.

CONCLUSION

Despite the oppressiveness of mid-twentieth century geopolitics, science, reflected in the impersonal neutrality of mathematics, physics, chemistry, and biology, is managing to breathe a little fresh air into an otherwise cold-war climate. Men and women of goodwill throughout the world watch hopefully as scientists of some 50 nations of the globe prepare for the International Geophysical Year (IGY), worldwide program of special observations of various earth phenomena planned between mid-1957 and the end of 1958. Scientists will cooperate in making simultaneous observations from a vast network of stations extending over the surface of the earth. The Foundation has responsibility on the part of the government of obtaining appropriations from Congress and for administering these funds, including coordination of federal agencies' interest in the undertaking. Federal appropriations to the Foundation to support the United States program are being made available by grant or transfer of funds to other government agencies and private institutions engaged in the work. Planning and technical direction of the United States program are in the hands of the United States National Committee for the IGY, which exists under the aegis of the National Academy of Sciences-National Research Council. The world program is coordinated by an international committee, Comité Spécial de l'Année Géophysique Internationale (CSAGI). Estimates of total world cost of the IGY vary from $200 million to $300 million. The Congress has appropriated $39 million for the United States program, about half of which will be used for the earth satellite program undertaken by the United States.

Although lay interest may center on the drama that will surround launching of earth-bound satellites and expeditions to the Antarctic, scientific interest will focus on measured data which will come from world-wide cooperative efforts of scientists who will collect and coordinate geophysical data on meteorology, upper atmosphere physics including the ionosphere, aurora, geomagnetism, oceanography, glaciology, seismology, and as a special additional program, redetermination of latitudes.

Such worldwide cooperativeness among scientists is viewed with mixed emotions, however, as the United States reflects on the portentous build-up of Soviet technology. Nevertheless, wise and sober observers of our own society and economy commend consideration of our own needs as the basis on which we should build a platform for United States science. Again, Dr. Killian of MIT articulated an apparent consensus viewpoint among scientists when he said:

> As we undertake to augment our supply of top-quality scientists and engineers, we should do so in terms of our own national needs and outlook. We need to concentrate more on the quality of our own science and technology and less on engaging in a technological race with the Russians and other nations. The last thing we should do is to engage in an academic numbers race with the Russians. We need, instead, to concentrate on those qualitative aims which will keep our science and engineering always ahead. The only sound policy is for the professions of science and engineering in the United States to seek in their own indigenous way to serve the growing needs of our society. This policy and objective, if followed, will require them to set quality and creativeness at the highest achievable level.

Quality and creativeness among its scientists will establish the United States in a position of leadership in conceptual science as securely as the United States now holds the front position among nations of the world in technological advances. Although comparatively young among agencies of the federal government, the National Science Foundation has already helped to improve the quality and is helping to assure the creativeness of United States science by attempting constantly to improve the environment of science and the quality of scientists through support of basic research in the sciences, providing opportunities to improve the training of scientists and engineers, gathering factual data necessary to recommend sound science policies for the federal government, maintaining a running account of United States scientific manpower resources, and encouraging a more complete and speedier exchange of information among scientists. However, these identifiable activities represent only part of the story—the very existence of the Foundation and the opportunity it provides for leadership in support of science in the federal government may well outweigh specific and tangible items. The position of trust which the Foundation has achieved in the university community is one which rests in part on the confidence built up during the comparatively short period of its existence. Indeed, the position of trust which the National Science Foundation has achieved among the people of the United States, reflected in substantial support of its policies and programs by the Congress, gives promise for a future when the United States will be accepted as widely throughout the world for its competence in conceptual science as it is now accepted for its technological leadership.

CHAPTER VI

Science Transforms American Agriculture

Ernest G. Moore and Stella S. English

Modern science and technology have transformed American agriculture in the space of a lifetime. Agriculture has made more progress in the United States in the last 75 years than in the previous 75 centuries elsewhere in the world. This period of great advancement coincides with the history of research in the United States Department of Agriculture and the state agricultural experiment stations.

Although research provided the original impetus for many of the changes in our agriculture, it was accompanied by growth and development of the country as a whole—expansion of agriculture, the upsurge of industry, transportation, and communication. The Extension Service is taking research directly to the farm. Agricultural outlook work and marketing services such as crop reports, official grades and standards, and the market news service, developed jointly with state departments of agriculture, have played vital roles. Research and development work by industry have been indispensable. In fact, all additions to man's knowledge everywhere have contributed directly or indirectly to the transformation of our agriculture.

What has agricultural research meant to an individual farmer, to agriculture as a whole, and to the nation? These questions lead to fascinating stories of adventure in distant lands and stories of great ideas coming to life in the minds of scientists working in dingy laboratories. In more recent times, the stories concern groups of scientists working as teams on common problems.

To a farmer, research means hybrid corn, disease-resistant crops, better control of insects and weeds. It means chicks and pigs that grow faster with greater efficiency and dairy cows that give more milk and butterfat. It means more intelligent use of his soils and forests and better methods of marketing what he has to sell. In short, it means a better living and a better way of life.

To agriculture as a whole, research means an increase of 30 percent in crop yields in the last 25 years, 25 percent more milk per cow, and an even greater increase in eggs per hen. Over-all efficiency has more than tripled in the last 50 years. In 1900 one farm worker produced enough for himself and 6 others; now he produces enough for himself and 19 others.

To the nation, agricultural research has meant the saving of lives, assurance of ample food supplies, and better nutrition for everyone.

While studying the cause and control of a cattle fever at the turn of the century, Department of Agriculture scientists discovered that ticks were carriers of the disease. To the average citizen this might seem to be a bit of routine information, but it was much more than that. It was the first positive proof that insects could carry a disease from one animal to another.

This discovery paved the way for later demonstration by medical research that mosquitoes were carriers of yellow fever and malaria. A Department scientist had already learned how to control mosquitoes by spraying kerosene on ponds and other small bodies of still water. These discoveries made possible the development of agriculture in vast areas throughout the world and saved countless thousands of lives.

Better understanding of food value and modern methods of refrigeration and distribution have greatly improved diets in the United States. Knowledge of the importance of vitamins, proteins, iron, and calcium in the diet has resulted in a shift to more protective foods such as meat, fruit, vegetables, eggs, and milk. In 1955 we ate 22 percent more dairy products other than butter; 29 percent more eggs; 30 percent more meat, poultry, and fish; and 12 percent more fruit and vegetables than we ate just prior to World War II.

And now let's take a closer look at some of the research that has revolutionized our agriculture.

CROP PRODUCTION RESEARCH

Hybrid corn is undoubtedly the food-production story of the century. Increased yields from hybrids are enough to provide an extra 40 pounds of pork (live weight) for every man, woman, and child in the United States. *Translated into dollars, this extra corn is worth enough every year to pay for all the research ever done by the Department of Agriculture.*

The story of hybrid corn begins about 100 years ago with Gregor Mendel, an Austrian monk, who cross-pollinated garden peas and observed the result (1866). Although his published work gathered dust for a third of a century, it was rediscovered and became the basis of our science of genetics, which dates from about 1900.

Within a few years two plant breeders in widely separated locations in the United States were crossing inbred lines of corn to produce hybrids. One was working at the Illinois Experiment Station, the other for a private foundation. Both observed hybrid vigor and saw its implications in increasing yields of corn, although neither was looking for practical results. They were pure scientists, looking for principles rather than practical applications.

For the next few years much time and talent went into research on hybrid corn. It was 1917, however, before its real potentialities were opened up by work at the Connecticut Agricultural Experiment Station that resulted in double crosses, the basis of all our present hybrids. Another decade passed before the public heard much about hybrid corn, but plant breeders were busily building inbred lines that would combine well to create hybrids adapted to specific areas. In an effort to speed up progress through exchange of breeding material, 12 states joined with the Department in a cooperative hybrid-corn breeding program in 1925. This joint effort did much to bring about the phenomenal spread of hybrids across the Corn Belt.

Like a prairie fire this new kind of corn swept across the central part of the country. In 1933 only 1 acre of corn out of each 1000 in the United States was planted to hybrids. Ten years later 52 percent of the corn land was planted to hybrids. Since then it has jumped to 90 percent and continues to grow larger, as hybrids are developed for new areas in the South.

Hybrids boost yields by an average of about 20 percent. For the whole country this means half a billion extra bushels of corn every year, worth at least half a billion dollars at farm prices.

Two extremely important points about hybrid corn should be borne in mind. First, it began with research that was purely theoretical, with no thought of practical application. The other point is that it took many years. We must not assume from this that every basic research problem is going to end up like hybrid corn, but most of our really big developments come from basic research. We must not become so eager for quick results that we are willing to write off a project that does not show definite gains every 12 months. If this had been done 30 years ago, we would not have hybrid corn today.

Science Saves Our Cereals

The magic wand of science has touched many other crops in addition to corn. Breeding of disease-resistant cereal crops over the last 50 years has saved many farms from bankruptcy, assured adequate supplies of a primary food crop to the whole nation, and helped to alleviate hunger in many parts of the world.

Stem rust and other diseases took an enormous toll until varieties developed through cooperative research with state agricultural experiment stations came into general use. When scientists learned that the rust organism spent part of its life on certain varieties of barberries, a large-scale campaign was organized to get rid of these plants. This proved to be a herculean task and is still going on.

Our temporary conquest of stem rust has not come easily. It was one of the earliest diseases to demand attention of cereal breeders. Scientists were puzzled to see a variety that had stood up for several years suddenly succumb. New varieties often met the same fate after a few years of successful resistance. For a while it looked as though we were losing ground as fast as we gained it.

One of the essential ingredients of science is ingenuity. It expressed itself in the mind and hands of a young scientist at Minnesota. He demonstrated that there were many races or forms of stem rust and that varieties of wheat or other cereals might be resistant to one race but not to another. This basic discovery explained many failures of the past and set up new guideposts for the future. It complicated the task of wheat breeders immeasurably, because they were fighting not one organism but a host of organisms, all capable of causing stem rust.

Later on it was learned that the rust spores were hybridizing in nature (during the period spent on barberries) at a faster rate than we were able to hybridize wheat and other cereals. This race between men and nature is still going on. We are only a few steps ahead. If we slacken our pace the gains of a lifetime will quickly disappear and the rusts will take over.

The recurring problem of plant diseases is well illustrated with oats. In Iowa, farmers have made a complete change-over twice since 1941 in the varieties of oats they grow, to keep ahead of diseases causing heavy loss. A third major switch was under way in 1956. Iowa growers realize the importance of improved varieties, developed through research.

Help for King Cotton

One of the measures of our progress in research is the casual way in which we speak of juggling chromosomes. We can breed almost any character we want in a plant if we work at it long enough and hard enough. But it was not always so. The idea of breeding plants to resist diseases is only about 60 years old. Selection of seed from superior plants has been practiced for centuries, but the earliest record of systematic selection for resistance to disease began in 1895 on James Island, near Charleston, S.C. The work was done by E. L. Rivers, plantation owner, in an effort to develop a strain of cotton resistant to wilt, a soil-borne disease.

Rivers was unable to combine disease resistance with yield and quality; so in 1899 he called on the Department for help. A young Department scientist from Vermont who had never seen a field of cotton was sent. Together these men made history by deliberately planting selected seed on wilt-infested soil and saving plants that survived. From this work several new varieties were eventually developed.

While this work was going on in South Carolina, the same story was unfolding in faraway North Dakota with flax, also beset by wilt disease. In both cases the principle of survival of the fittest was applied by scientists. This principle is now widely used in all crop improvement work.

In the intervening years the cotton plant has been the beneficiary of much research. It was redesigned to meet the threat of boll weevils and the requirements of mechanical production, and now a rather major overhauling appears imminent.

Breeders are developing new and vastly different varieties that offer enormous potentialities for cotton to compete with synthetic fibers. They are developing triple hybrids with fiber strength almost double that of present commercial varieties. These triple hybrids aren't ready for release yet, but they are far enough along that several strains are now included in spinning tests. The germ plasm for these promising new cottons was obtained from three sources: an Asiatic variety, American upland cotton, and a wild species that grows in the mountains of Arizona.

What has been done for wheat and cotton has been duplicated with most of our major crop plants. Thousands of improved varieties have been developed that thrive better under specific conditions. Some are resistant to insects as well as diseases, and others are more tolerant to drought, heat, or cold; some combine many of these qualities. Still other varieties yield better quality food or industrial products.

PLANT HUNTERS BRING 'EM BACK ALIVE

Much of our success in crop improvement can be credited to foreign germ plasm brought back by plant explorers who have combed desert valleys and wind-swept mountain peaks for wild relatives of our principal crops. About 230,000 separate lots of plant material have been brought or sent to this country through the plant-introduction work begun by Benjamin Franklin long before the Department existed, and later made famous by David Fairchild.

In its early stages the principal objective of plant exploration was to find new crops for our expanding agriculture. Settlers brought the grains, fruits, and vegetables they had known in Europe, and these were supplemented by private and public means. One of the most notable of Department introductions was the soybean. As originally introduced, the soybean would never have made a big hit in the United States, but plant breeders worked it over and made it a Cinderella crop. It now ranks fifth among all our crops in acreage.

Many crops threatened with extinction have been saved through plant breeding. New varieties of sugar beets restored that industry in the West when curly top disease seemed a sure winner. Sugar cane brought from the wilds of New Guinea by a Department scientist who braved head-hunters and other dangers of the tropics gave new life to our sugar cane industry, then on its last legs. Bright-leaf tobacco in North Carolina and lettuce and cantaloupes in California are additional crops dramatically saved from threats of extinction by ravishing diseases.

Breeding Vim into Vegetables

A few years ago it was not at all unusual to hear farmers complaining that their seed stock of potatoes had "run out." They meant that yields were getting smaller every year. Tomato growers over large areas lost entire crops from wilt, and cabbage growers were in trouble with a disease known as yellows. Nationwide breeding programs were organized, with state and federal agencies cooperating, and most of the commercial varieties of these and other vegetable crops now in use are an outgrowth of this teamwork.

The lady with the shopping bag who buys America's groceries has influenced the improvement of fruits, vegetables, and other crops. If she likes potatoes with shallow eyes, we develop them for her. If she wants strawberries with a tart flavor, she may have them. Lined up behind the plant breeders are other scientists whose job it is to see that these and other fresh food products are delivered to the retail markets in prime condition. To round out the job, we are now teaching retailers how to care for these foods so that the consumer may get them in their most attractive, nutritious, and appetizing condition.

Scientists remember, however, that beauty is only skin deep. Today's foods are bred for the highest possible vitamin and mineral content, consistent with other market qualities. Tests for vitamin C are now routine in many plant-breeding laboratories.

Improving farm products and producing them more efficiently have gone hand in hand. Efficient production is a combination of many things, one of which is usually mechanization.

MECHANIZED FARMING

While corn pickers and grain combines as well as many other machines have been perfected by the farm equipment industry, much work has been and is being done by agricultural engineers in public service research in devising requirements and operating principles for mechanizing such crops as cotton, peanuts, tung nuts, sugar cane, sugar beets, tobacco, sweet potatoes, and many truck crops. Similar work also is being done in such fields as haying, weed-control methods, sprayers and dusters, fertilizer placement, and tillage equipment and methods.

Intensive work in the mechanization of cotton growing has resulted in practical methods for better use of flame in weeding and thinning cotton, and special equipment for applying anhydrous ammonia. Of special note also are equipment combinations for multiple duties in speeding field operations in this crop, such as a planter-cultivator combination that permits replanting of "skips" in the stand without changing the tractor equipment even up to the final cultivation.

Cotton-ginning investigations carried on by the Department have resulted in many improvements in this process. Numerous public patents have been issued on devices developed by engineers on this work. Perhaps the most important of these deal with the artificial drying of seed cotton and include machines, apparatus, and methods. A line-flow lint cleaner, which improves the quality of machine-picked cotton, has helped materially in making possible the mechanical harvesting of this crop. An even more recent development is a feed-control device, which permits optimum drying, cleaning, and ginning of bulk seed cotton. Similar studies have speeded machine production and the processing of such fibers as flax, sansevieria, and ramie.

Sometimes it is simpler to fit a crop to an existing machine rather than build a new one. Sorghum was made into a dwarf by plant breeders so that it could be harvested with a combine. Soybeans were made to bear their seed pods higher on the stalk for the convenience of the harvester. Sugar beets have been redesigned to take the stoop out of the thinning and weeding operation. A single sugar beet plant with monogerm seeds (one seed to each seed ball), found in 1948, gave breeders just what they had been looking for. They transferred the monogerm character into commercial hybrids to permit the spacing of single plants along the row—so that thinning and weeding can be done mechanically. In this case, a machine was also needed, so engineers modified the cotton chopper and made a mechanical sugar beet thinner.

SOIL AND WATER CONSERVATION

In spite of the many improvements in methods of crop production, our average yields per acre did not increase very much until about 1935. Until then, soil deterioration was progressing at a rate sufficient to offset all other improvements. Since then we have had large increases. Many of the gains are due to better varieties and such things as more effective insecticides. However, we are beginning to slow down soil deterioration and in many cases stop it and start on the upgrade.

We have learned to classify farm land for its most productive use and to adapt these plans to individual farms. Research has made possible the use of all classes of land in the most effective way. We are recognizing the factors that make cultivation of land hazardous and working out patterns of safe land use. When erosion and other soil deterioration are controlled, our advances in other lines will appear even more striking.

Closely associated with conservation of the soil is the effect of numerous improved tillage and terracing practices that conserve soil moisture. Our ceiling on crop production is probably going to be set by the amount of water available for crop growth. As we get better varieties of crops and apply other results of research, water will become even more important.

We have lots of room for improvement in the conservation of water. In the humid region, we are now losing through runoff about one-fourth of the rain that falls on continuously cultivated crops and about 15 percent on rotated crops. Efficiency of irrigation in the West is only about 25 percent. But we are making some progress. Stubble mulch culture traps snow for use of crops in the Plains. In some areas of the higher Plains we can save an extra inch of snow moisture by planting shelter belts. Land-use practices for many land conditions have been developed that increase infiltration rates and thereby reduce losses of water.

SOIL MANAGEMENT

Research on the use of fertilizers and methods of soil management has revealed many facts useful to farmers in aiding nature to make specific soils more productive. Much has been learned about the use of crop rotations, legumes, and green manures for replenishing soil humus and nitrogen; about procedures for determining the nutrient needs of crops; about materials, methods, and machines for meeting these needs efficiently; and about soil management under irrigation and salinity control.

Because techniques based on these findings have been put to use on many farms throughout the country, productivity is on the comeback in many areas where yields were falling off because of declining soil fertility. On hundreds of thousands of farms in the eastern part of the United States the soil is much better today, as a result of good management, than it was under natural conditions.

On the other hand, there are still many farms on which soil productivity is on the down grade. For some, improved methods of soil management are available, but not in use. For others, new techniques are still being worked out. For the nation generally, we have not yet fully reversed the downward trend in soil productivity.

More extensive use is being made of fertilizers in agriculture, and more efficient fertilizers are being developed through public and private research. During the past 15 years, farmers in the United States have more than doubled their use of chemical fertilizers, and they are now applying them in granular, liquid, and gaseous forms. The importance of the minor plant nutrients such as zinc, iron, cobalt, copper, boron, molybdenum, and manganese is becoming more generally understood. When minor element deficiencies show up in various agricultural areas, ways are being devised for correcting them.

RADIOACTIVE TRACERS

A significant recent development in soils research is the use of radioactive isotopes. Scientists have unlocked a vast storehouse of knowledge about plants by using radioactive isotope tracers to follow the processes by which plants take up the materials of the earth to yield fruits, grains, and fibers.

Radioactive elements give off a radiation as they disintegrate. This radioactivity makes it possible to detect or trace the radio-element wherever it may go, in the soil, through the plant, and in an animal.

For example, scientists can fertilize a soil with radio-superphosphate, grow clover, feed the clover to a cow, and feed a calf on the cow's milk. After being on such a diet for a month, the calf's bones can be analyzed for total radio-phosphorus. From the data, scientists can calculate the amount of phosphorus in the calf's bones that came from the superphosphate put into the soil.

Significant advances in fertilizer technology have been made since the end of World War II by using the radioactive tracer technique. Scientists have learned the phosphorus needs of various plants at different stages of growth and the efficiency of different phosphates. Radioactive isotopes are being used to study other phases of plant physiology such as learning how plant-growth regulators change a plant's growth and why they affect some plants but not others.

Radioactive isotopes are also being used for irradiating plants to induce genetic changes or mutations that may be useful in breeding improved crop varieties. Most of the effects of radiation are bad, but scientists are finding some irradiated plants that contain new and desirable characteristics. Cereal breeders, for example, report promising preliminary success in finding disease-resistant plants through radiation research.

Radioactive materials have given us new tools for work on animal pests, too. One of our most intriguing experiments resulted in the complete eradication of the screwworm fly from the island of Curaçao in the Netherlands West Indies in 1955. The females of this serious livestock pest mate only once. Entomologists exploited this fact by saturating the wild population with thousands of laboratory-reared male flies, made sterile by exposure to gamma rays from radioactive cobalt. The sterile males so greatly outnumbered wild male flies that eventually every egg laid failed to hatch.

Entomologists think it may be possible to work out similar procedures for controlling or eradicating the screwworm fly from infested areas of the mainland. The method looks promising for controlling certain other insects, too, and studies are going on in Hawaii with several species of fruit flies.

We're just beginning to learn how to use radioactive materials as tools in our study of soils, plants, and animals, but what we've learned so far is showing us the rich potentialities of atomic energy in agricultural research.

RESEARCH AIDS OUR SHRINKING FORESTS

Next to the soil itself, our greatest natural resource is our forests. We waited a long time to become concerned over the exploitation of this source of fabulous wealth. Our grandfathers were busy conquering a continent. Our fathers finally began to take stock of the situation about 50 years ago, and it is only within comparatively recent times that we have put science to work to help us use our forests intelligently.

Early research in forestry reflected the temper of the times. It was concerned chiefly with measuring forest products and estimating volumes of standing timber on a given tract of land. It was used mainly as a tool in the exploitation of our timber, region by region.

The next era was one of awakening, and forest research turned to finding the minimum requirements for keeping our forest lands productive. Experiments in many parts of the country proved that forests can be managed so as to produce annual crops through selective cutting. Small holdings now provide a worth-while supplemental income every year to many farmers.

In some areas, however, millions of acres of forest land have become barren without any hope of natural reproduction, because all seed trees have been destroyed. For these lands, research has found ways to grow young trees in nurseries, transplant them, and make them live. Planting machines have been developed that save up to 50 percent of the usual planting costs.

Besides getting trees to grow on denuded areas, we are also learning how to make them grow faster. Hybrid poplars in Maine are yielding four times as much wood per acre as native poplars. A cross between Eastern and Western white pines was twice as tall as either parent at 7 years of age. Crosses between several species of Southern pines are producing hybrids more useful and, in some cases, more vigorous.

Forest Range Management

Much of our forest land is also range land. Almost half the entire continental area of the United States is range land, and this vast empire has suffered from overuse. Research has shown definitely that the ranges respond to good management.

A grazing experiment in Colorado with beef cattle gave annual returns per section of land of $735 for moderate grazing, compared with returns of $484 under heavy grazing. Desert ranges in New Mexico are now producing almost twice as much beef per acre under good management as they did 30 years ago under poor management.

In some areas good management must be supplemented by reseeding, and our experience has been very encouraging. Reseeding on many Western ranges has increased the supply of forage from 5 to as much as 20 times. So far, about 10 million acres of private and public range have been reseeded.

Closely related to research on forests and ranges is that on watershed management. This research has contributed to the development of a national policy of soil and water conservation. This policy has already been reflected in legislative recognition of the role of upstream lands and conditions in downstream water and silt troubles and the adoption of nationwide programs to remedy these troubles on a watershed basis.

Livestock Research

Every man, woman, and child in the United States and countless millions in other parts of the world are the beneficiaries of livestock research. These dividends in human welfare have come about as a byproduct of efforts of the Department to safeguard and improve our domestic livestock.

The epochal discovery that pointed the way for control of malaria and other diseases carried by mosquitoes has already been mentioned. Another scourge of the human race was conquered when Department scientists discovered the New World hookworm and identified it as the cause of much of the apparent laziness of many people in tropical and subtropical climates. Control of this parasite in humans as well as in livestock for the last 30 years has been based directly upon the work of agricultural scientists.

Research has also protected the American people from trichinosis—a painful and sometimes fatal disease caused by eating raw or insufficiently cooked or cured pork products. Trichinae, minute parasites that occur in the flesh of hogs, are transmissible to human beings, causing trichinosis. The parasites in pork can be destroyed by heat, by special kinds of freezing, and by certain concentrations of common salt.

These discoveries were important in meat inspection work, because trichinae cannot be detected by any known practical method. Under packing-house conditions the discoveries have been applied to processed pork products such as frankfurters, sausages, and hams that may be eaten without further cooking. Meat inspection regulations now provide for special processing, under vigilant supervision, of these pork-containing products.

The meat inspection service of the Department operates entirely for the benefit of consumers. Because of this service we in this country can eat meat and meat products with every assurance that they are wholesome. Those who have not traveled abroad do not always appreciate this security.

As recently as 1910 many people, including doctors and public health officials, regarded pastuerized milk as unsafe for babies. It was believed by many that pasteurizing milk killed all of the lactic acid bacteria in it and allowed the growth of undesirable organisms that produced toxins. In other words, they felt that pasteurization did more harm than good. It took years of painstaking work for a Department bacteriologist to prove that pasteurized milk was safe even for babies and invalids to drink.

When Department veterinarians developed the now famous strain 19 vaccine that protects calves from brucellosis they were working to safeguard our livestock primarily, but indirectly they were working for the alleviation of human suffering. A related form of this disease—undulant fever—attacks man, and may be transmitted by drinking raw milk from a cow that has brucellosis. Through cooperative effort of state and federal governments this disease is gradually being eliminated from our herds of dairy cattle.

DDT was discovered in Europe about 75 years ago, but its usefulness as our most versatile insecticide was discovered by entomologists of the Department. It has been used in more ways to protect more crops and livestock from insects than any insecticide ever discovered. But far beyond these values, its use in protecting troops in World War II from flies, mosquitoes, and lice—and the diseases they transmit—have made it a boon to mankind.

These examples illustrate the kinship of all branches of science. When we push back the curtain of darkness in any spot, the light of truth illuminates much more than just that spot. It may, and often does, penetrate other dark areas. It may flash across a continent in the process or it may come into sharp focus in an Iowa pigpen.

Conquest of Hog Cholera

Hogs were dying by the thousands in Iowa in 1897, when a young Department scientist spent the summer vainly trying to stem the tide with a serum made from the bacterium thought to be the cause of hog cholera. This epidemic, as others had done, finally spent itself and farmers were able to grow hogs once more.

It was 6 years before there was another disastrous outbreak of hog cholera in the Middle West. In the meantime, the young scientist had gone to school and earned an M.D. degree by night while carrying on his search for the true cause of hog cholera by day. His industry was rewarded with the discovery that hog cholera was caused by a filterable virus, rather than bacteria. He also discovered that hogs surviving the disease were immune for life.

When he went back to Iowa in 1903, he was armed with more potent weapons. First he found that blood from immune hogs would give temporary immunity to others. But this was too cumbersome; he was looking for a permanent treatment. Then as he watched farmers burying their dead hogs, an idea was born. Why not combine the protective serum with live virus from the blood of a sick hog for lifetime immunity? It worked, and losses that often mounted as high as $65 million in a single year were reduced to a small fraction of that amount. Use of the serum-virus treatment for immunizing pigs is now standard practice wherever hogs are grown.

Not all of the conquests of science are so dramatic as the saving of millions of hogs from cholera. Others are a result of cool calculation in an effort to satisfy, or even anticipate, demands of consumers. One of these demands has been for less fat and more lean cuts of pork. Export and domestic demand for lard began dropping soon after World War I, and the depression made matters worse.

This situation presented a challenge to scientists—a challenge to redesign the American hog, to stretch him out and take off those excess pounds of fat. The first step was to import several animals of the Danish Landrace breed, developed for export to England, where demand calls for lean pork. This breed was crossed with several domestic breeds, both at Beltsville and at state experiment stations. The objective has been a streamlined hog with less fat and more of his total weight in the choice cuts (ham, bacon, loin, shoulder, and shoulder butt).

New strains developed by selective breeding from these crosses provided the answer—and more. They not only produced more lean meat and less fat; they also produced larger litters and bigger pigs, which in turn grew faster and required less feed to reach market weight than the average farm pig. Even more important, the scientists found that farmers can develop these leaner, better producing hogs within any breed by selecting breeding animals with meat-type characteristics.

The meat-type hog was not an overnight development. It took 16 years to make it a commercial reality. And the story isn't ended yet. The job still remains to encourage more farmers to grow the better meat-type hogs and to encourage buyers to look for them on the market and pay a premium for them. This educational job is being carried out by many groups, both in government and in the livestock industry.

Some of the most significant research on breeding of livestock has been done with dairy cattle. This work has covered about 35 years and has established the proved sire system of breeding. This system discards much of the show-ring emphasis on type and conformation of animals and stresses the point that determines the size of the milk check—production.

Much of the success of the artificial-breeding movement in the last 15 years is due to the availability of proved sires and the opportunities for farmers to breed their cows to these superior bulls. Artificial breeding associations now provide service for about one-fourth of the nation's dairy cows. Proved sires plus artificial breeding give every dairyman in the United States opportunities to improve his herd undreamed of only a generation ago.

TAILOR-MADE LIVESTOCK

Earlier in this report it was pointed out that science can breed almost any desired character into a plant if given enough time. It is usually more difficult to do this with livestock because of the longer time between generations, lack of sufficient numbers, and other complications. In spite of these limiting factors, however, we have made a good start in breeding farm animals that are tailor-made for certain conditions and special needs.

A good example is the Columbia sheep, a breed made to order for the intermountain area. It combines the best features of the Lincoln and the Rambouillet in a breed that economically produces more good wool and more meat than any breed available in that area.

The meat-type hogs were bred to meet consumer demand. The same is true of the Beltsville Small White turkey. It was developed several years ago to meet requirements of modern housewives, who want smaller turkeys to fit smaller refrigerators, smaller ovens, and smaller families. It is now in heavy commercial production.

A more recent request was for good dairy cows that could take the long hot summers of the Gulf Coast region. We went to India for breeding material this time. The Red Sindhi breed was developed there for heat resistance, so we imported several young animals of a strain developed by American missionaries. These have been crossed with Jerseys, and several of the crossbred offspring are now on test at Beltsville, Maryland, and Jeanerette, Louisiana. It is yet too early for final evaluation, but it has definitely been established that tolerance to heat can be bred into dairy cattle.

Interesting results have been obtained by crossbreeding chickens for special purposes. In recent years sexing young chicks has become standard practice on many poultry farms. When New Hampshire males are crossed with Barred Rock females, all female chicks will be black and males will be black with a white spot on the head.

READING THE FUTURE OF ANIMALS

Science is concerned with many aspects of farm animals. One of the most practical is predicting at an early age if the young animal will grow into an efficient milk or meat producer.

Success has been realized in predicting the future of dairy heifer calves at Beltsville when they are four months old. The degree of mammary gland development at that age is a good index of future production. The method is now being tested on dairy farms, and if it proves to be practical under farm conditions we may be able to weed out poor producers at four months of age instead of much later.

Another instance of foretelling the future occurs in beef cattle breeding, in which we are cooperating with 35 States and Hawaii. The idea of proved sires has been borrowed from the dairy cattle breeders, but the conventional way to prove a sire was to test the performance of his offspring. Careful records have shown that it is possible to predict some of the performance characteristics of a bull's offspring by using his own vital statistics, and those of his brothers and sisters. This is especially true of rate of gain and efficiency of gain.

The value of performance testing is becoming generally recognized, and a number of states now have extension specialists working directly with beef cattle breeders in the improvement of their herds. In 1956, a national performance registry association was formed for beef cattle.

Studies of young chicks show that they too give indications of future development at an early age. Early development of wing feathers is a good indication of rapid feathering, which in turn means fewer pinfeathers. Careful examination of day-old chicks reveals whether they will develop feathers quickly or slowly. Weight at 1 month is a good index of future gains up to approximately 12 weeks.

The Darkest Place in the World

A famous editor and educator once said the darkest place in the world was the inside of a dairy cow. What he meant, of course, was that we knew far too little about the life processes that take place inside our farm animals. Although we still have a long way to go, we have made some headway in studying farm animals, particularly from the standpoint of nutrition.

Because of the immediate returns in the milk pail, the feeding of dairy cattle has received a great deal of emphasis in research. A seemingly simple discovery many years ago has saved a lot of grief for milk drinkers, most of whom doubtless never heard of it. The discovery was that feed flavors and odors are transmitted to the milk directly through the body of the cow. As a result of this work, it is an unwritten law on dairy farms to feed directly after milking rather than before or during the milking period.

Grass silage owes its popularity to research. Several years ago a survey showed that summer butter contains 60 percent more vitamin A per pound than butter made in winter, when green feed is less abundant. This stimulated more research on grass silage. Tests at Beltsville have shown that as much as 50 percent of the protein and 90 percent of the carotene in standing green forage may be lost between cutting and feeding. Preservation of forage crops as grass silage or by barn curing saves more of these nutrients.

Feed is a subject near the heart of all poultrymen. One of the most important items of the feed bill is protein. Research prior to World

War II gave rather exact requirements for protein, minerals, and vitamins, both for growing birds and for layers.

During the war, animal byproducts became scarcer and scarcer. More and more soybean meal was substituted in poultry feeds as a source of protein. This change in poultry rations brought on new troubles. We found that, without animal protein, the hatchability and livability of chicks went down as the level of soybean meal in the hen's diet went up. With animal protein the troubles disappeared.

In the midst of the dilemma, one of our scientists found that these troubles could be overcome by feeding small quantities of dried cow manure to hens whose eggs were to be used for hatching. He concluded that the manure contained a growth substance or unknown vitamin also present in animal byproducts.

Research men at a commercial laboratory who were also working on the problem isolated a new vitamin, B_{12}, which proved to be the elusive unknown. Since B_{12} was known to be formed by microbial action, industrial researchers turned to the residues of antibiotics as a possible convenient source of the vitamin. In these studies they discovered that antibiotics themselves stimulate growth in poultry and swine. Other research findings included the discovery and use of riboflavin and, more recently, other additives such as arsenical compounds and animal fats. Feed manufacturers have been quick to take advantage of these developments by changing their feed formulas to incorporate the new growth-promoting supplements. As a result, poultry farmers can produce a half-pound more poultry meat on a broiler with a half-pound less feed than they could with the rations available 20 years ago.

This kind of research sells itself, because it is easy to see that it could make the difference between working for pay or just for the fun of it. We have done many other things—far too numerous to mention here—that shed some light on what our editor friend called the darkest place in the world. In all honesty, however, we must admit that the inside of a dairy cow is still a pretty dark place. And the same can be said for the other classes of livestock on our farms.

Research Teams Up with Service

Research is the backbone of most of our service activities that affect livestock. It has been pointed out how these team up in the meat-inspection work. The same teamwork exists in many other activities.

One of the early tasks assigned to the Department of Agriculture was fighting livestock diseases, some of which are transmissible to man. The first to be conquered was pleuropneumonia of cattle. The dread foot-and-mouth disease has been eradicated six times since the turn of the century. About five years ago, a deadly form of Asiatic Newcastle disease was detected and eradicated before it could spread to our poultry flocks.

Two diseases receiving concentrated attention at present are brucellosis and tuberculosis of cattle. Both have caused heavy economic losses to the livestock industry, and both represent a problem in human health. Tuberculosis has been almost eradicated; only about $1/10$ of 1 percent of our cattle now have it. Before the national program of testing and eradication of diseased animals was begun several years ago, it was not unusual for herds, particularly in heavily concentrated dairy areas around our large cities, to show 25 to 40 percent infection.

Progress is being made in eradicating brucellosis, but the fight here is far from finished. Of about 14 million official blood tests made in 1955, there were slightly more than 2 percent reactors. Maine, New Hampshire, North Carolina, Washington, and Wisconsin have achieved a "modified brucellosis-free" status—less than 1 percent infection. Several other states are rapidly approaching this status.

Another way in which the Department protects the nation's livestock is to quarantine all animal immigrants—a kind of Ellis Island for livestock. If animals show symptoms of disease while they are in quarantine, they are not released until they are entirely recovered.

MAN'S WAR ON INSECTS

The endless war between man and insects has been dramatized by many writers, and some have gone so far as to predict that insects will be here long after man is gone. While some of us take a more hopeful view, we do not for a moment underestimate the strength of our opponent or the severity of the struggle.

Insects have the advantage of numbers. Entomologists estimate that there are more than a million different kinds of insects on the earth, and that the total number would be a figure so large that it wouldn't have any meaning.

Insects multiply with incredible speed, and they have the further advantage of being able to adapt themselves to almost any condition. This accounts for the fact that insects have been present on this planet much longer than man and have seen many forms of life appear and disappear.

Recent events illustrate the adaptability of insects. For a while it seemed that DDT would practically spell the doom of some of the worst actors of the insect world, such as flies, mosquitoes, lice, and many crop pests. Now, however, they are developing resistance to this amazing insecticide.

Decisive Battles

The record of Department scientists in this war is filled with many victories, some of which at the time seemed almost disastrous to the foe. In the late nineties, for instance, Department entomologists recommended to the public the drainage of swampy areas and use of kerosene on still bodies of water to control mosquitoes. This recommendation was based upon studies of the life history of the major malaria mosquito in this country. These methods, now supplemented by DDT and other new insecticides, are used all over the world.

Screens for doors and windows and screened porches are taken for granted by most people in this country. However, their value in providing protection from malaria was demonstrated by experiments of the Department only about 30 years ago. Use of screens is now a "must" in all parts of the world where malaria is a health factor.

But not all of our early guns were trained on mosquitoes. First public interest in the control of houseflies was aroused by the Department, and its battle cry "swat the fly" was heard around the world. This campaign, like that on mosquitoes, was backed by facts concerning the life cycle and feeding habits of the enemy.

Experiments prior to 1900 showed that flies breed most extensively in barnyard manure and that proper sanitation would go a long way toward controlling them and the diseases they carry. Later on, household and barn sprays came along, followed by aerosols or mist sprays. The aerosol principle became the basis of the famous aerosol bomb used so widely during the last war by our troops and since the war by everyone.

The most decisive battle to date in our war on insects was the development of DDT. It rocked the insect world and completely changed large-scale control methods against flies, mosquitoes, and many other insects.

Mankind's ancient enemy, typhus, can easily be prevented by controlling its carrier, the body louse. A typhus epidemic raging in Naples, Italy, in 1944 was stopped in its tracks by use of DDT.

Strategy of Current Campaigns

We have also won some notable victories over insect enemies of crops and livestock and those that invade our homes. Sometimes we do this by setting one insect against another. Sometimes a simple change in a farm practice will turn the trick. In some cases we can develop crop varieties that have natural resistance to insects. When none of these methods work, we resort to poisons in the form of insecticides.

The first planned use of one insect to control another took place in 1888-89 when a Department entomologist was sent to Australia to find and bring back an insect that would control cottony-cushion scale—also native to Australia—then threatening to destroy California's growing citrus industry.

This trip seemed a long-shot gamble, and the Congress refused to appropriate funds for it. The Department's head entomologist at the time was a resourceful administrator, and he arranged to have his man sent over as a delegate to the Melbourne Exposition, for which funds were already available. Needless to say, the entomologist spent little time at the exposition but scouted the byways and hedges. His mission was successful, and his work has become a classic of modern science.

The way we outwit the Hessian fly by delaying the planting of winter wheat is a good illustration of fighting insects by changing a farm practice. Entomologists thought this one up many years ago, but until that time Hessian flies were one of our major pests of wheat, causing losses as high as $100 million in some years. Many farmers now delay planting of wheat in the fall until after the fall egg-laying period of the fly is over.

We are making increasing use of built-in resistance to insects by developing new strains and varieties of plants that insects don't like. Examples are varieties of corn resistant to the corn borer, corn earworm, or chinch bug; wheat resistant to Hessian fly; barley resistant to green bug; sugar beets resistant to leaf hoppers; and alfalfa resistant to aphids. Some of these are already available; others are in the process of development by entomologists and plant breeders.

The final plan of action, when we cannot get results from the others, is to use insecticides. It is true that we use chemicals more often than other measures, but that's because they're more effective against most insects. We can't work the delayed planting strategy against very many, and breeding for resistance is slow and expensive work. It's true we have been successful in using many predatory or parasitic insects to control certain enemies, but this method won't work across the board.

New Insecticides Turn the Tide

DDT has upset the enemy in more instances than could possibly be listed here. It took care of codling moth, the cause of wormy apples; it controlled the corn earworm; and it saved the day for cotton growers. It made possible the control of forest insects that rank right along with fire as plunderers of our shrinking forests. It worked wonders against many livestock pests that levy a heavy tax on our milk and meat production.

For a while, we thought DDT had won the battle of the bugs. Then, after a few years, our confidence began to dwindle—as the bugs began to fight back. One insect after another began to show resistance—mosquitoes, lice, roaches, and codling moth, potato beetles, lygus bugs. Fortunately for us, however, our entomologists didn't stop with DDT. It was only the first of a long list of organic insecticides that proved far more effective than the old-time inorganics. We are testing hundreds all the time. When one fails to do the job, we try another.

In many cases a combination of two or more of the new chemicals gives better results than either alone. This has been true against many fruit, vegetable, and cotton insects. Combination insecticides that kill the major pests of cotton in one application is the greatest single advance thus far in our war on these pests.

The war on insects is not confined to stock pen, field, or forest, but must be waged on the home grounds and inside the home. Here, too, we have won some notable victories. Homeowners and others can now control Japanese-beetle grubs by applying a small quantity of a powder to the soil. This powder contains spores of a disease that kills grubs in the soil. A single, simple application lasts indefinitely.

Clothes moths and other household insects have survived all our stratagems of the past, but we think we have most of them cornered now with our new weapons.

An entirely new approach to insect control was discovered a few years ago in certain organic insecticides that can be applied to seeds or plants, or fed to animals and be absorbed in the system. Certain insects that feed on these plants or animals are killed. Cotton seed, for example, treated with thimet is protected during the seedling stage—an important period from the standpoint of insect damage. Dow ET-57 fed to cattle will destroy grubs in any stage of development. The idea of controlling insects with systemic insecticides offers great promise and work is progressing in many locations throughout the country.

Another new trend is greater use of attractants as a means of insect control. For example, we are getting good results in using baits against DDT-resistant houseflies and fruit flies. We're also using baits successfully in our fruit fly detection surveys.

The increasing use of chemicals to control insects has brought increasing concern about the residue problem. We must be sure that they will do the job of killing the pests without leaving chemical residues on the crops that will be harmful to beneficial insects and to animals or man. Before a new insecticide is recommended for commercial production and use, our scientists make exhaustive tests to assure its safety when used properly.

FIFTH COLUMN THREATENS

The insects that we are fighting here on the home front are just a part of our total enemy. There are more species waiting to set foot on our shores than have already landed. These form a fifth column that staggers the imagination. If they got in, they would more than double the tax we now pay to insects, and they might wreck some parts of our agriculture altogether.

Many of the insects that now give us the most trouble are those that have slipped in when no one was looking. They leave behind their natural enemies and settle down. Some more familiar examples are European corn borer, Japanese beetle, Mexican boll weevil, and Hessian fly.

The only guard that stands between us and these hordes of pests is a thin line of federal plant-quarantine inspectors. These men are stationed at the principal ports of entry to examine baggage and other articles brought in by travelers. This is a service that goes on 365 days a year, largely unknown to the people whose crops and orchards are being protected.

Dangerous criminals of the insect world are turned back almost every day in the year by these inspectors. These insects come by ship, by rail, auto, and airplane. They come secreted in packages of food, in wrappings of gifts, and especially in baggage. Parcel post packages are another favorite means of infiltration.

This threat from foreign insects is one that we have to live with, but we had better not forget about it. Just a few of these invaders could establish a beachhead that could wreck our future plans of production.

We've been able to drive out foreign insect invaders in a few instances—the Mediterranean fruit fly and the Parlatoria date scale, for example, and we've prevented or retarded the spread of others, such as the gypsy moth, white-fringed beetle, and pink bollworm. In these latter instances we're still hopeful our entomologists will find ways of eradicating them, just as they are now doing with the new weapons in use against the gypsy moth in certain areas of the Northeastern states.

FRIENDLY INSECTS WORK FOR US

The insect world is full of strife, just as is ours. Fortunately for us many insects live on others, recalling the jingle:

> Big bugs have little bugs upon their backs to bite 'em;
> Little bugs have littler bugs, and so ad infinitum.

Insects also die by the millions from disease. We take advantage of predatory and parasitic insects and diseases to control pests whenever possible. Our search for allies among the insects goes on constantly.

One of our oldest allies is the honeybee. From Biblical days up to a few years ago this little symbol of industry pretty much escaped the ministrations of science. But now we have disturbed its simple life with artificial breeding. We want to control breeding and build up the bees to be better servants of man. We are well along the way, with inbred lines and hybrid bees, somewhat like hybrid corn.

The production of honey is no longer our chief requirement of bees. We want them to pollinate our crops, many of which will bear no seed or fruit unless they are pollinated by insects. Modern agriculture, including some of our modern weed killers, insecticides, and farming methods, has done badly by some of our old friends such as bumblebees that used to pollinate fruit and forage crops.

As a result, we must depend on the growing beekeeping industry to supply honeybees to do the pollinating job. In California, since 1951 when the practice of placing hives in alfalfa fields got under way, yields of seed have more than doubled. Research has shown that the yields of hybrid cotton seed also can be increased by placing honeybees in the fields as pollinators.

UTILIZATION RESEARCH

In the early days of the Department and state stations the main problems were in production. Export markets were good and no one worried about surpluses. It has been only in comparatively recent years that we have been concerned over new outlets.

Utilization research is essential to efficient production and marketing. It is aimed at improving existing foods, fibers, and other farm products, at creating new ones, and at finding uses for farm wastes and residues. Much of this work is done at the four large regional research laboratories, which have been in operation about 15 years.

These laboratories truly exemplify science in action. The tasks assigned to them are nearly always extremely complicated, and many of them require long and involved work of a fundamental nature. Sometimes the job calls for taking an agricultural material apart, molecule by molecule, and reassembling it to make a new product.

The old notion that chemists could make silk purses out of sows' ears has given way to the idea that they are the people who make nylon out of coal, air, and water. Most of the work is not so startling, but a good bit of success has been realized.

PENICILLIN AND STREPTOMYCIN

Our contribution to commercial production of penicillin contained all the elements of the dramatic and spectacular and was a high spot of wartime research. It was a race with death, depending on how fast science could coax microscopic molds to work.

Our scientists reasoned that somewhere just the "right one" existed. They sought the magic micro-organism in every corner of the earth available to us at the time and finally found it in their own back yard—growing on a spoiled cantaloupe in the Peoria city market. Then it became a question of feeding it just the right diet to make it work at breakneck speed. The fact that the British already knew the value of this wonderful new medicine lent drama and suspense to the race.

Just as brilliant achievements of an individual are often built upon tedious years of study and preparation, so was the penicillin accomplishment based upon many years of experimentation with molds by Department chemists in a search for more efficient ways to convert farm commodities into industrial products. One of the best known examples is the conversion of starch from corn or potatoes into industrial alcohol. The process is also used to produce yeasts, vitamins, and other ingredients of feed.

The penicillin story is only one example of agricultural research that has given us new and useful medicines. Many other antibiotics have emerged from agricultural laboratories. The most famous among these are streptomycin discovered at the New Jersey station and its relatives, chloromycetin, aureomycin, and terramycin.

When war started in Korea in 1950, the need for a blood plasma substitute became acute. Various dextrans (a starchlike substance made from sugar) were tested and some showed promise, but this country had no method whatever for making the material. Agricultural scientists went to work, in cooperation with the National Research Council and medical units of the military establishment, and within two years, found a way to produce a clinical dextran in quantity at a reasonable price. Dextran unquestionably saved thousands of lives in Korea and is now available for civilian use. It costs about one-fourth as much as blood plasma and can be sterilized and stored without refrigeration.

MAKING COTTON MORE USEFUL

Cotton has been the subject of much research since establishment of the regional laboratories. This work is laying the foundation for improved cotton goods better able to meet increasing competition from synthetic-fiber products. Research is demonstrating that cotton's natural qualities can be improved by chemical modification of cotton fibers, yarns, and fabrics. Discoveries resulting from this work are now in commercial use.

One of these is a simple dye test that makes it easy for cotton mill operators and cotton dealers to estimate the relative maturity of lint cotton, and thus to find out in advance how it is likely to behave during processing. If lint cotton contains a fairly large proportion of underdeveloped, thin-walled fibers—commonly known as "immature"—it often spins poorly and may cause dyeing defects in the finished goods. The method of detecting immature fibers depends upon the different reactions of mature and immature cotton to a special mixture of red and green dyes, and is now widely used throughout the cotton industry.

Cotton yarn and fabric highly resistant to rot and mildew and able to stand greater heat than ordinary cotton is another recent development. This new cotton looks and feels like the regular product but lasts much longer. It is made by a chemical treatment called partial acetylation, and has been adapted for commercial production.

SCIENCE ON THE DINING TABLE

Another important segment of our utilization research deals with foods. Early work of the Department on the detection of adulterants in foods provided the foundation for the pure food and drug laws early in this century. Later work aided the expansion of our food-processing industries and helped to standardize marketing practices among producers and distributors of fruit and vegetable products. Today science is making our foods more appetizing and easier to prepare. We Americans never sit down to eat without having a liberal sprinkling of science in our foods.

As mentioned earlier in this chapter, the citrus industry of California was saved by introducing a friendly insect from Australia to stop the ravages of a scale insect that was killing the trees. Many years later the industry was in trouble again—this time from overproduction

—and again called on the Department and state agencies for help.

The result was a whole array of citrus byproducts, including lemon oil, orange oil, citrate of lime, and citric acid from cull fruit. Pectin, marmalades, and stock feeds joined the list. These items, together with improvements in handling and transporting the fruit to Eastern markets worked out by Department horticulturists, helped to get the industry back on its feet.

Frozen concentrated orange juice offers another example of research coming to the rescue of the citrus industry. Orange growers in Florida were in clover during World War II, when the government was buying large quantities of fruit for processing and shipment overseas, but they were foresighted enough to know this demand would not last. Accordingly, the Florida Citrus Commission and the state experiment station cooperated with the Department to improve frozen citrus juices.

Events proved the wisdom of the Florida growers. Prices dropped below costs of production in the 1946-47 season. As conditions grew worse the chemists again came up with the answer. Frozen concentrated orange juice was an instant success and is now a familiar item on the breakfast tables of millions of American families every morning.

In the meantime, other frozen concentrated fruit juices have been developed and are now on the market. Some of these are frozen concentrated lemon, tangerine, grapefruit, grape, and apple juices.

More recently, processes have also been developed for converting fruit and vegetables juices into stable, palatable, convenient-to-use powders. Orange, lemon, apple, prune, grape, and tomato juice powders of excellent taste and keeping-quality can now be made. They can be stored on the kitchen shelf with other staples, and reconstituted quickly even in ice water.

Former GI's remember too well the unappetizing dried eggs served to them during World War II. We simply did not know how to dehydrate eggs that would hold their flavor in storage. After the war, however, scientists found that the sugar glucose in the egg was the culprit. They worked out methods for destroying the glucose by yeast fermentation or by enzyme treatment. The glucose-free dehydrated eggs store safely for several months even at 100 degrees F. The new dried eggs have put whole-egg cake mixes on every grocery shelf in the country. They also make good scrambled eggs.

Other food research that is bringing more appetizing foods to our tables, which can be mentioned only in passing, has resulted in frozen orange and lemon purees, fruit essence from apples, grapes, and other fruits, improved dehydrated potatoes, a froth flotation process for cleaning peas (borrowed from the mining industry), and improvements in the processing of pickles.

More about Soybeans

Soybeans would never have reached their present high rank among our major crops if new food and industrial outlets had not been found to stimulate demand for greater production. Scientists in the Department, the states, and industry have developed hundreds of uses, including such varied products as plastics, paints, waterproofing materials, glue, foam material for fire fighting, food shortening, and coating for shotgun shells.

Turpentine Farmers Live by Research

To most of us turpentine is something that's used to thin paint or to remove it from our hands or clothing. But to 40,000 farmers in the Southeast, it is a livelihood. These farmers are making a good living out of pine gum, source of gum rosin and turpentine, long known as naval stores. Most of them carry on other farm operations and work their pine trees as a side line. No crop in America owes more to research.

Conservation and fire-protection programs have helped immeasurably to maintain and increase the productivity of second-growth pine stands along the South Atlantic and Gulf coasts. Department researchers have found ways to treat pine trees with an acid spray that stimulates them to increase the flow of gum. Gum-processing methods have been radically improved, and the yield and quality of gum turpentine and rosin have been increased.

Modernization of turpentine farming began in the late twenties. Department scientists developed a new gum-distilling process using steam distillation to replace the primitive fire stills that had dotted the piney woods country for 150 years. A few years later a process of gum cleaning lifted most of the rosin from lower grades to the highest, and a method of dehydrating turpentine improved its quality.

These improvements revolutionized the gum naval stores industry. They led to the construction of efficient central distilling plants and made pine gum an ideal "butter and egg crop." Gum can be collected and sold during 9 or 10 months of the year, and, if the fish are biting, the job can be delayed a few days without loss. A continuous-steam still is the latest gift of science to this ancient industry.

NEW USES FOR AGRICULTURAL WASTES

The American passion for efficiency is exemplified by our large meat packing houses, where, according to the familiar saying, all of the pig is used except the squeal. Our agriculture has suffered from the lack of such efficiency in controlling waste, but research has not ignored this problem.

For many years the Department has investigated practical ways to use agricultural wastes and residues of various kinds, including wheat straw, corncobs, waste vegetable leaves, and the pulps and juices from fruit canning plants.

Our truck farms grow 7 to 8 million tons of a dozen major vegetable crops every year, but less than half of this production reaches the consumer. The remainder consists of leaves, vines, and other materials that are discarded at packing houses and processing plants. Yet many of them are rich in proteins, minerals, vitamins, and other nutrients. Practically all of this material goes to waste.

Many other crops contain valuable residues. We have millions of tons of unused wheat straw, cornstalks, and corncobs, for example. By and large, only about half of our farm production in terms of plant material finds worth-while use today. Here is a compelling challenge to research in the future. We have already made a beginning.

Practical methods have been developed for drying waste vegetable leaves and converting them to high-protein leaf meals for livestock. The value of these meals as a good source of protein and carotene has been demonstrated in actual feeding tests.

Substantial advances have been made in the economical utilization of waste fruit and vegetable juices in fermentation processes for production of industrial alcohol, yeasts, vitamins, other feed constituents, and antibiotics. Large quantities of corn steep liquor, a byproduct of the corn refining industry, and milk sugar, a dairy byproduct, are used in the production of penicillin.

Even the lowly corncob is finding a use in industry. For many years corncobs have represented a waste problem on the farm. They pile up in corn shelling plants. Several years ago, our research people found they could make a chemical known as furfural from corncobs. Furfural has many industrial uses, one of which is in the manufacture of nylon.

In a free-enterprise system such as ours, it is normal for some commodities to compete with each other in the market place. One of the reasons why the demand for lard began dropping after World War I was the competition of vegetable oils for shortening. The same thing has happened to inedible animal fats—beef and lamb tallow and waste pork fat left from meat-packing operations.

These waste fats used to be the main ingredient of soap. Then synthetic detergents came along and made terrific inroads into the soap market. During the last decade, the consumption of animal fats by the soap industry has been cut in half and surpluses have been building up.

Scientists faced the challenge of finding new market outlets for fats surplus as well as for the 1.5 million tons that are produced each year. The problem has not been solved yet, but progress is being made. As a result of research, millions of pounds of inedible fats are now going into livestock feed and into plastics and other industrial products. And it now looks as if fats may win back some of the market lost to synthetic detergents. Our scientists have produced detergents from animal fats that will compete favorably with the synthetic products, and a large meat packer plans to put pilot-plant quantities of these animal-fat detergents on the market in the near future.

Skimming the Cream in Dairy Products Research

From inedible animal fats to tasty dairy products is a pleasant change, but the imprint of research is still there. Our dairy scientists have improved practically every dairy product in existence, and many that we take for granted today are the offspring of research.

We would not think of eating the kind of butter prevalent in the gay nineties. It was made from unpasteurized sour cream and, in storage, developed odors described as metallic, oily, and fishy. Much of this butter, of course, was a total loss so far as human food was concerned. Scientists of the Department proved that butter of good flavor and keeping quality could be made from pasteurized sweet cream, and the industry adopted the practice.

Our domestic Swiss cheese industry is a result of combining modern science with an ancient art. American cheddar cheese has been vastly improved, chiefly through the use of pasteurized milk. Packaging of cheese in small consumer sizes with transparent wrapping in which the cheese ripens cuts out the rind loss and has greatly stimulated consumption. Pasteurization has stepped up the output of No. 1 cheese from about 25 to more than 90 percent of total production.

When outbreaks of disease during World War II were traced to the eating of fresh cheese made from raw milk, several states enacted legislation requiring pasteurization of the milk as a substitute for a long ripening period. Enforcement of these laws was greatly helped by a method worked out in United States Department of Agriculture laboratories for checking on pasteurization. The method was later modified for use with practically all dairy products.

When milk is consumed fresh or as evaporated or condensed milk all of the nutrients are utilized. But when it is made into butter or cheese the story is far different. Butter utilizes fat and vitamin A, and cheese utilizes most of the protein and fat and some of the milk sugar and salts. The rest of the vitamins, the minerals, and the milk sugar are left in the skim milk and whey. These products, for the most part, are either inefficiently used or wasted.

This situation has not been ignored by research people, and they have made a good beginning toward making better use of these valuable food nutrients.

As a result, consumption of non-fat dried milk solids has more than doubled in the last 10 years. The recently developed non-fat milk powder that reconstitutes instantly is causing a big boost in consumer demand for this highly nutritious dairy product. The use of non-fat dried milk in bread, cake mixes, and other foods is also increasing.

Another new product, sweetened condensed whey, is being used by confectioners in fudges and caramels. Dried whey is being used in cake and other food mixes and in certain canned soups.

The list of new foods from agricultural research is long and varied. These are merely samples of what is being cooked up in our scientific kitchens. Samples of such cooking were presented at a special luncheon for the Agricultural Research Policy Committee at Beltsville some time ago, and even some of the staff were frankly amazed at what was offered to the guests.

One of the primary objectives of utilization research—and all our other research, for that matter—is the welfare of our population. This calls for finding out by experiment and then promoting in every way possible the wise use of the foods we produce.

NUTRITION FOR EVERYONE

Agriculture must supply the kinds and quantities of foods to meet the health needs of all our population. This requires exact information on the nutrients different individuals require in the various age groups. We must also know how much of each nutrient the various foods supply.

Nutrition scientists now measure the amounts of amino acids and proteins required for maintenance and for periods of growth and building up, and they are preparing tables giving the amino acid content of the proteins in important foods. Fats, too, supply certain essential acids. The requirements for these are being studied, and the amounts in food and fat are being measured to assure that requirements for health are supplied.

It is hard enough to acquire these basic facts, but sometimes it is even more difficult to get people to use them. While our nutrition workers are getting these facts in the laboratories, others are making surveys to find out what people are buying and eating. For the last 60 years the Department has had an insatiable curiosity about what people eat. This information shows us where we are skating on thin ice and points up the opportunities to improve our diets at no increase in the food budget. Sometimes it even shows how we could save money in the process of choosing foods wisely.

Changing people's food habits is a large order, but we already have ample proof that it can be done. Earlier we mentioned some of the changes in consumption since 1939. Schools are doing the job—the place where it does the most good—and home-demonstration agents and youth groups are helping. Publications of every description, from the most technical to the most popular, have been issued by the Department and distributed by the millions. As a result of educational programs nearly everybody today knows about the basic seven foods, about the value of milk and the other protective foods, and about the need for a good breakfast every day in the week.

A good lunch is also a good idea, particularly for school children. Our food-preparation scientists have teamed up with the School Lunch Program of the Department and developed recipes for school lunch use. Quantity recipes and guides for lunch planning and for buying food to meet Type A lunch requirements have been developed and published. This and similar work in home and institutional food preparation teaches and demonstrates good nutrition at one and the same time and helps to make use of foods often in abundant supply.

Nutrition is just one part of home economics. Others include studies of clothing and textiles, home equipment, and houses designed for more efficient and convenient living and working.

Clothes for the Working Woman

Clothing scientists have pioneered in designing women's clothing suited for farm work, indoors and out, and to factory jobs. These designs include dresses, coveralls, raincoats, and other garments and provide for comfort, freedom in work activities, convenience, and safety.

The first designs set a standard for a new large branch of the work clothes industry. Within a few months about 100 companies were putting out garments following the Beltsville designs or making use of the functional principles illustrated.

Practical aid to the clothing industry and better fitting garments for the consumers are resulting from an unusual Department study made a few years ago. It is said that at least $13 million worth of children's clothing is returned annually to retail stores because of inadequate sizing and marking systems. Scientific measurements of 150,000 children and 15,000 women were made, and improved systems for sizing garments have been worked out, in cooperation with industry and the U. S. Department of Commerce. This work is eliminating much waste due to misfits.

Care and Serviceability of Fabrics

Fundamental research relating to care of clothing and household fabrics has been focused on construction of knit goods as related to serviceability, the chemical properties of fabrics as affected by new combinations of home bleaches and detergents, the masking of yellowness and soil with fluorescent dyes, the removal of soil by detergent and perborate bleaches, the removal of stains by home methods.

Disinfecting and sanitizing levels of different types of germicides have been determined for cotton and wool fabrics contaminated with suitable test organisms. The most effective treatment of fabrics of different composition to impart bacteriostatic properties economically has been determined by varying the ratios of germicide-fabric-weight and volume of disinfectant.

Long-term serviceability studies of sheeting, children's knitwear, men's cotton shirts, percales, draperies, carpets and men's suitings are providing valuable information for the homemaker.

Homes Planned for Efficient Living

Research in housing is establishing space requirements and efficient arrangements for work and storage areas of the home based on physiological costs and physical requirements for space. These requirements are then translated into guides for architects and planners so that houses of the future, particularly farmhouses, will more nearly meet the needs of families.

Every family that uses modern household equipment benefits from our work. A laboratory is maintained at Beltsville for studying such large and small appliances as freezers, refrigerators, washers, and flatirons. Their performances are evaluated from engineering and in-use standpoints, and the findings, together with suggestions for improvement, are submitted to the manufacturers. Many of the suggestions are incorporated into the designs of the next models.

The Story of a Ladder

The science of wood utilization hit the front pages of every newspaper in the country several years ago in connection with the most famous and sensational kidnaping case in our history. Officials were baffled; their chief clue was a short ladder, but to ordinary crime-detection experts ladders made of wood do not tell their secrets.

Someone thought of Department scientists at the Forest Products Laboratory and asked for a wood expert. Like a bloodhound he traced the lumber from the ladder back to the lumberyard and on back to the purchaser. With this guiding information, nabbing the criminal and convicting him was made possible.

To many newspaper readers the Forest Products Laboratory was an unknown quantity, but not to thousands of wood and lumber users. They had been taking their problems to the laboratory for many years.

The newspapers themselves and their readers owe a debt to the science of forestry. Fifty years ago spruce pulpwood furnished most of our paper, with some help from balsam, hemlock, and poplar. Scientists found ways to use some of the more plentiful species, such as the Southern pine, Douglas fir, and many of the hardwoods. Yields have also been increased.

One of the most interesting stories of wood concerns the rather simple thing of fastening together two or more pieces of timber. First we used wooden pegs, then metal drift pins, nails, bolts, and finally modern metal connectors that make it possible to design wooden structures with engineering precision. The laminating of beams, arches, and other structural members has been brought to a high state of development to provide a means of making small pieces do the work of large timbers, as the large trees of our virgin forests disappear.

Plywood has been transformed from a whimsical product whose behavior was unpredictable into a dependable material that can be used for exterior building purposes.

We have learned much about wood chemistry. Cellulose can now be changed to sugar and it in turn to ethyl alcohol, feed yeast, molasses, or other products. Lignin is a potential source of alcohols and many other chemicals.

More than a million tests have been made at the laboratory to get exact information on the properties of 175 native woods and materials derived from wood. With modern glues developed by research the gluing of wood has progressed from a traditional and secretive process into a well-established commercial operation free of trade secrets and hocus-pocus.

Seasoning of lumber has been changed from a slow process dependent upon nature for heat and air circulation to a highly specialized scientific process. Wood-preservation treatments have been vastly improved and are in wide use now. Other treatments prevent swelling and shrinking, and still others can make softwoods behave like hardwood.

Economic Research for Farmers

Farming today is a business that requires high-class economic counsel based on the most reliable data that can be brought together. Efforts to provide this began more than a century ago with federal collection of a few statistics on farm production. Today economic research on the organization and operation of farms and on the impact upon farmers of technological progress, of changing supply and demand conditions, of varied developments throughout the domestic and world economies has become a major activity both in the Department and in the land-grant colleges.

Economics of Production

Each new machine, each new practice that comes from laboratory or field plot poses new questions for the dirt farmer. He needs to know, "Will it pay? How can I change my farming operations to make it pay?" Combining the separate contributions of research on plants, animals, and machines into efficient and profitable systems of farming is a never-ending task in this age of rapid technological advance.

Farm budget analysis has been developed into an effective farm management research tool for dealing with this problem. Today in some of the state experiment stations the most promising combinations of crops and livestock developed through farm budgets are being tested on research farms under practical farm conditions. On these farms the results of many unrelated lines of research are being fitted together into farm plans that will work, area by area. This synthesizing of the work of the natural scientist and the engineer with that of the economist is still in its infancy. It holds great promise for hastening the application of research results on farms throughout the nation.

The value of research in farm organization management was dramatized in World War II. It furnished the basis for much of our program for mobilizing agricultural production. We had to have information on needed acreage of crops, numbers of livestock, size of labor force, amounts of machinery, gasoline, and other items. The Department was able to furnish this information.

With the cooperation of the land-grant colleges, the productive capacity of agriculture was analyzed as a basis for yearly production goals to meet the nation's wartime needs. Many farmers were asked to make drastic changes in their operations. Economic research helped them plan these adjustments efficiently and indicated the prices and other inducements necessary to encourage ventures into new lines of production.

Not all production problems can be resolved by farmers acting as individuals. Conservation and utilization of land and water resources, land tenure and land values, zoning, agricultural credit, insurance and taxation, all present economic problems of broader implication. Federal and state research have contributed to improvements in farm leasing systems, to putting farmers' mutual insurance on a sound basis, and to preventing a repetition of the overexpansion of farm mortgage credit that led to the debacle in farm real estate following World War I. National programs for specialized farm credit, for crop insurance, for encouraging sound conservation measures are built on the foundation stones of research in these fields.

Economic Advisory Service to Farmers

Agriculture today is one of the several major industries in a close-knit economy. Both farmers' individual success and the national well-being depend heavily on the ability of farmers to adjust their business in the light of a multiplicity of economic developments.

Thanks to agricultural economics research, farmers faced with this need have an economic advisory service which is today on a par with that available to any segment of industry. Starting with the first annual outlook conference, in 1923, this work has expanded into a year-round service providing current information on supply, demand, price, and other trends for every major group of agricultural commodities.

Information on significant developments, both at home and throughout the world, is continuously assembled and analyzed by agencies of the Department. Results of this research are rapidly disseminated, through the periodic situation and other reports, to economists and extension specialists in the states, to the farm press, and to farm leaders and advisers throughout the country. They adapt this information to local conditions or problems so it will be most useful to individual farmers. The usefulness of current research on the economic outlook as a guide to farmers in planning their operations depends on getting the information to them as quickly as possible. The speed with which this material is disseminated is therefore a major achievement.

MEASURING THE ECONOMIC SITUATION OF FARMERS

Scientific analysis of any problem depends first of all upon identification and measurement of many factors. In economics this requires devising workable combinations of diverse statistical data. Our success in this constitutes a major achievement in agricultural research.

The indexes of prices received and of prices paid by farmers are early fruits of research ingenuity in tackling this problem. These indexes made possible the concrete formulation of the "parity" goal for agriculture as embodied in our basic farm policy legislation. Other index numbers provide composite measures of crop yields and farm production, of total and average per capita food and fiber consumption, of the farmer's share of the consumer's dollar, of farm costs and returns, of farm employment and wage rates, of farm land values—indeed of virtually all the economic factors significant for appraising the situation of agriculture as a whole and of its many segments.

"Farm population" has been meaningfully defined for use in the decennial census, and measures of farm family levels of living have been devised for comparison between areas and with other population groups. Systems have been developed for economic classification of farms and type-of-farming areas, and the financial condition of farming as a whole has been uniquely portrayed in the annual balance sheet of agriculture.

For no other segment of the economy do we have so adequate and so effectively organized a body of statistical measures of economic conditions as for American agriculture. They form an outstanding and essential part of our national economic statistics. They are the foundation for appraising current economic developments. They provide the basis for determining the farm adjustments which are needed to most effectively meet our consumption and foreign trade needs.

These varied services of agricultural economics research have come to be largely taken for granted by the farmers, businessmen, and agricultural leaders who rely upon them for information and guidance. They have become the accepted basis of fact for policy formulation both by Congressmen in the enactment of legislation and by executive branch officials in program administration. They play their role, in partnership with research in the natural sciences, in the continuing progress of American agriculture toward the twin goals of greater productivity and higher levels of living for agricultural producers and of more abundant supplies of farm products to meet the nation's expanding needs.

MARKETING RESEARCH AND SERVICES

In the discussion on production and utilization, attention has been called to many instances of research that were prompted by changing conditions in the marketing of farm products. The purpose has been to show that no branch of agricultural research can be carried on intelligently without considering the others. Marketing requires more than the usual consideration, for it influences our other research in so many ways.

Plant breeders wouldn't think of introducing a new variety of wheat without making sure of its milling and baking quality. New food products developed in the laboratories don't get very far unless they have that certain something that makes people willing and eager to buy them. In a highly developed agriculture such as ours, the marketing process demands the best talent we have for research, service, and educational work.

As long as farmers grew everything they needed and their wives made everything the family used, there was no marketing problem in American agriculture, and hence no need for marketing research or services. With the expansion of agriculture and specialized production of crops and livestock, farmers became aware of the marketing process.

The railroads did much to sharpen this awareness. Farm products began to travel long distances to big cities, and buying and selling were no longer a face-to-face transaction between neighbors. Farmers, often in debt, rushed their produce to market at harvest time, causing oversupplies and ruinous prices. Wide spreads in prices received by farmers and those in retail stores convinced farmers that they were not getting fair treatment. Farmers blamed the middleman and demanded action from state and federal governments.

Consumers also were demanding action by the government. Unsanitary handling of meat in the packing houses, dramatized in Upton Sinclair's book, *The Jungle,* led to the federal meat inspection service. Other abuses in the commercial handling and preparation of foods led to the passage of the pure food laws in 1906, administered for many years by the Department.

In the decade between 1914 and 1924 the Congress responded to the demands of farmers with several sweeping actions that helped to put farmers in a better position to deal intelligently in the market place. One of the first of these was the market news service, created in 1915.

Market News for Every Farmer

If the value of a Department service were to be measured by the space it receives in the daily press or by the amount of time it gets on the air, market reports would be in the No. 1 position. These reports are now carried by some 1200 daily newspapers and close to 1400 radio stations, not as a service to the Department but to readers and listeners. Although market reports, of one kind or another, are available to every farmer in the United States—either at the mailbox or over the kitchen radio—there are still commodities and markets on which farmers need more information.

Of course, it was not like this at first. In the first few years the reports were issued at a few of the larger cities and covered only fruits and vegetables. Since then the service has been expanded to cover all major farm products. As an economy measure, the Department was told to abolish the service on July 1, 1933. Notices went out only about a week prior to this date, but during that week an avalanche of letters, telegrams, and telephone calls left no doubt about the value of this service to the trade as well as to farmers. The service, therefore, was not discontinued.

There is a story in the Department that an official sensed the need of a market news service 10 years before its creation and figured out a plan for its operation. However, when he estimated the cost, including a leased-wire network—very much as we have it today—he discovered that it would cost almost $1 million a year to operate such a service. He concluded that it would be impossible to get that much money, and the idea was dropped. Events later proved that his idea was not only practical but a necessity of modern agriculture.

Selling Farm Products by Grade

The market news service could never have amounted to much without uniform grades and standards for farm products. Fortunately, the two services developed concurrently. It wouldn't have meant much to a farmer or to elevator operators to know that wheat was bringing from $1.50 to $2 a bushel unless all parties knew what kind of wheat was bringing each price.

Passage of the Cotton Futures Act in 1914, requiring the use of federal standards in trading in cotton futures, definitely established the Department in standardization work. Grades of a sort were in use as far back as 1825 in New Orleans, but the grade names were not tied down to a fixed standard. The need for uniformity was voiced by growers and domestic spinners, as well as by cotton merchants and exporters.

Confusion in the cotton trade was no worse than that in grain. In 1906 there were 133 grades for wheat, 63 for corn, and so on down the line. Some states had their own official grades. Boards of trade in the large grain centers also had their own grades for grain, and very few of these agreed with one another. Buying a pig in a poke was a relatively safe transaction compared with buying or selling grain.

This situation was corrected by the Grain Standards Act of 1916. Other commodities were covered by later legislation, and now we have official grades for practically all agricultural products. Their use has spread from the wholesale markets to the retail field, where butter, eggs, turkeys, rice, dry beans, potatoes, canned fruits and vegetables, and other commodities are being sold on the basis of grades. From the beginning, much of this work has been carried on in cooperation with state departments of agriculture and bureaus of markets.

Other important legislation of 1916 included the Warehouse Act, which made it possible for farmers to store staple commodities safely while waiting for a more favorable market. In effect, warehouse receipts proved to be a very useful form of credit for farmers and marketing agencies, as they could borrow money on these receipts.

Inspection of farm products by federal-state inspectors, another big step in developing our marketing system, was authorized in 1917. This gave farmers an impartial referee and put a stop to many abuses. This work also plays an important part in settling disputes among shippers, carriers, and buyers in the big cities. Inspection also is an essential feature of price-support programs and marketing agreements.

LEGISLATION CORRECTS ABUSES

Another chapter in the history of marketing was written in 1921 with the passage of the Packers and Stockyards Act. This legislation recognized public stockyards as a public utility, subject to public regulation by the Secretary of Agriculture.

Still another landmark appeared in 1922 with passage of the Grain Futures Act, which gave authority to the Secretary of Agriculture to regulate trading in grain futures. This was a response to the longstanding suspicion among farmers that trading in futures was just another way of driving down the prices of their products so that big profits could be made by professional traders. The Grain Futures Act and other similar legislation was incorporated into the Commodity Exchange Act as amended in 1936.

The Produce Agency Act of 1927, and the Perishable Agricultural Commodities Act of 1930 were among later developments that broadened the protection to farmers, and incidentally helped the reliable produce dealers. These acts required buyers and commission men to show financial responsibility and to accept obligations to fulfill contracts.

These regulatory acts represented profound changes in our way of life, and this brief treatment of them should not suggest that they were as simple as adopting a new type of cultivator or a new breed of livestock. Extremists on both sides were dissatisfied when these laws were passed. Those on one hand cried out against government interference, while those on the other side demanded that the federal government more strictly regulate buying and selling of farm products.

Mounting surpluses and falling prices for farm products in the twenties brought forth many proposals for giving relief to farmers. Prominent among these was a call for an expansion of marketing services and regulatory authority of the government. We have seen how many of these proposals were put into effect. The market news service was strengthened, standardization was broadened, and commodity futures markets were regulated. The Department began its economic outlook programs to guide farmers in planning production and marketing. This was the first of many subsequent efforts to help farmers adjust production to effective demand.

Crop Reports Keep Farmers Posted

Basic to all government services to farmers are the crop and livestock estimates of the Department of Agriculture. This is by far the oldest of our economic services, beginning in 1839 with the first appropriation ever made by the federal government for agriculture. Collection of agricultural statistics was one of the two major lines of work specified in that first appropriation. However, only a few annual crop estimates were issued from 1841 to 1845 and then they were stopped.

Beginning in 1863 the Commissioner of Agriculture published monthly reports on the condition of crops. The reporting force during this period was a nationwide voluntary group of county crop reporters.

In 1866 annual reports on acreage, yields, and production of important crops and livestock numbers were begun.

As the service developed, estimates of production became a regular part of it. By 1920 production estimates were made for 29 crops and for wool. Condition reports were issued for 44 crops. A continual research program has been conducted in recent years in an effort to improve the estimates. In fact, the modern science of statistical sampling and forecasting had its origin in the work done by the Crop Reporting Board.

In the present comprehensive program, crop, livestock, and price estimates currently released in more than 500 reports each year, lend themselves to a wide array of practical uses by farmers and dealers in farm products. Their current usefulness is heightened by the fact that a broad background of continuing series of data on agricultural production now covers a span of 90 years.

It would be hard to imagine the condition of our agriculture today without these marketing services. Certainly the technological revolution brought about by research in production could not have progressed as it has without benefit of similar, though less spectacular, developments in marketing. Farmers try out new practices such as chemical weed killers, for example, when they have sufficient funds to make the investments that are often necessary. Without the additional income provided by improvements in the marketing process, many of our improvements in production might still be waiting for adoption by farmers.

Valuable as these marketing services have been, each new emergency, each new farm production and marketing problem turned the spotlight on the need for more marketing research. When the Research and Marketing Act was passed in 1946 only 4 percent of the Department's budget for research was being spent on marketing research. This does not take into account the basic economic research, much of which is fundamental to all applied research in marketing. Neither does it take into account the large volume of production and utilization research, already referred to, that owes its existence to changes in consumer demand. But even with these explanations, it does show that marketing research was lagging.

RMA A LANDMARK IN AGRICULTURAL LEGISLATION

In the Department and at the state stations, marketing research has lagged far behind that on production. This situation led to the passage of the Research and Marketing Act of 1946, Title II of which gave special emphasis to marketing research, service, and education. The RMA brought about several innovations in our operations. One was the research advisory committee system. Some 30 commodity and functional advisory committees, headed by a national Agricultural Research Policy Committee, meet at least once a year with Department officials to discuss and make recommendations on the federal research and related programs. These committees, representing producers, processors, and marketing groups, constitute a two-way communication between the Department and the citizens of the country. Another result of the RMA has been the development of regional research. Groups of states get together on common problems and set up regional projects under the guidance of a regional technical committee. Federal agencies may, upon the invitation from the committee, participate in such regional projects.

The RMA also gave the Secretary of Agriculture authority to contract for research and service work outside the Department whenever the work "can be carried out more effectively, more rapidly, or at less cost than if performed by the Department." As a result, approximately 10 percent of our marketing research appropriation is being used for contracts with private research firms, research foundations, industrial laboratories, universities, and other public or private agencies.

There is now a very broad program of work going on under authorization of the RMA, the marketing provisions of which are known as the Agricultural Marketing Act. Although the 50-year lag in marketing research has not yet been overcome by any means, progress is being made. A few examples will illustrate.

Improving Market Facilities

One of the first marketing trouble spots attacked was the markets themselves. Many of our market facilities were built more than 100 years ago, and it is not surprising that they do not fit today's concepts of efficiency. They operate with horse-and-buggy efficiency in a jet-propulsion age.

This problem was brought into focus by research in the thirties, and a beginning was made on a solution. The work is primarily an advisory service on planning the location, design, and operation of markets for fruits, vegetables, poultry, meats, and other foods.

The marketing specialists study the needs in a given city and prepare a detailed report which amounts to a complete blueprint for building, financing, and operating a market. The plan explains what kinds and sizes of facilities are needed, the best locations for them, what they would cost, how they could be financed, how they should be managed and operated, what the savings over present facilities would be, and an estimate of benefits to farmers, distributors, consumers, and the community at large. In accordance with these plans, new and modern markets have been built in numerous cities—among them San Antonio and Houston, Texas; Louisville, Ky.; Birmingham, Ala.; Rochester, N. Y.; and St. Louis, Mo. Savings in costs of handling and increased volume of business in some of the new markets are running into millions of dollars a year.

Application of engineering methods to increase efficiency is likewise being extended to packing plants, warehouses, processing plants, and even wholesale and retail stores. A big problem in stored grain is keeping it dry to prevent spoilage. The usual method of drying is to turn the grain, which requires moving it from bin to bin. This calls for an extra bin and added labor in transferring the grain. Recent research has demonstrated that the drying can be done more effectively and much more cheaply by circulating air through the grain. For example, a Texas elevator operator with five steel storage tanks installed a mechanical aeration system and reported that the system paid for itself in less than a year. In addition to eliminating the cost of moving the grain (sorghum in this case), he was able to store 26,000 bushels in the extra bin. Based on similar reports of storage operators who have installed the mechanical aeration system, it is estimated that at least a million dollars a year can be saved as the method becomes more widely adopted.

One of the factors contributing to the price spread in perishables between producers and consumers is the high rate of spoilage and breakage during marketing. Research is showing where the losses occur and how they may be reduced through better equipment and more efficient handling. A new table designed for packing cartoned eggs, for example, not only cuts down on breakage but also reduces employee fatigue and increases productivity.

Finding Out What People Want

Sometimes our marketing research takes us to city consumers, where scientifically selected groups are interviewed to find out their preferences. Where do they buy? What do they buy? Why do they buy it? Such information is useful not only to farmers, but to processors, retailers, and others interested in getting farm products used. Recent studies have been conducted to learn how people make up their minds in deciding between different fibers and fabrics in selected items of men's, women's, and teenagers' clothing. In a nationwide sample survey among women, for example, more than half of those interviewed said they had no criticism of cotton and all cited one or more things they liked about it. Leading the list were laundering qualities, durability, appearance or style, and coolness. They preferred cotton fabric for housedresses and aprons, summer dresses and skirts, blouses, and sportswear (slacks, shorts, and anklets). Cotton rated second for between-season dresses, raincoats, and slips. Information obtained in the survey was used by the cotton industry in educational programs and has helped cotton more than hold its own in the wearing apparel field in spite of the increasing use of synthetic fabrics.

A survey of consumers in one city, to learn what kinds of breads they prefer, brought out their preference for the lighter, fluffier breads with relatively high content of milk solids and sugar. The findings are expected to help bakers in providing the kinds of breads that are most liked, and so, perhaps, to retard or stop the long decline in per capita bread consumption.

Other consumer preference studies—on wool, fruits, meats, poultry, and other farm products—have also given practical information.

Marketing costs for California orange growers have been greatly reduced by transportation research. For years shipping regulations required the air vents of refrigerator cars to be closed as soon as the outside temperature reached 32°F. Under these conditions cars loaded with warm oranges had to be iced to prevent spoilage. Scientists found that icing was unnecessary during winter months if the air vents were left open while the trains passed over cool Western mountains. Shipping regulations were revised, and the growers and consumers pocket the ice money.

Similar studies have shown California tomato producers how to cut costs and put better quality fall-grown tomatoes on Eastern markets by using just enough ice to maintain the shipping temperature around 55° to 65°F.

An instrument for detecting blood spots in eggs was developed in another research project, and a public service patent was obtained. The device, after commercial-scale tests, should reduce materially the cost of packing eggs by eliminating much hand labor. Blood spots are a principal problem to large-scale producers of eggs in plants where other quality factors are carefully controlled.

WHO GETS THE CONSUMER'S DOLLAR?

Previous to the Research and Marketing Act, the Department made many studies of price spreads and published this information widely. However, relatively little was done toward measuring the cost of specific marketing functions such as wholesaling, transportation, processing, and retailing. This type of research has been stressed since the additional marketing funds became available, and a series of reports in this field has recently been published.

One report explains why the marketing bill for food went up $23 billion between 1940 and 1955. The volume of food marketed increased more than 40 percent. Because of the general rise in all prices and costs, charges for performing marketing operations roughly doubled. The marketing system is providing more services—packaging, processing, and more convenience foods—that add to the labor and cost required to move foods from farm to consumer.

Another report presents six examples of individual marketings of cattle from ranch and farm through the marketing, slaughtering, processing, and wholesaling and retailing levels to the ultimate consumer—based on actual average price quotations. The study shows that the differences between costs and selling prices can vary greatly, yielding different margins for similar services at different times.

A study of bread showed that consumers in 1955 paid 70 percent above the price they paid in 1946. Of the 7.3-cent increase per loaf, about ½ cent went to farmers and 6.8 cents to marketing charges—mostly to bakers. The rise in bread prices corresponded rather closely to the rise in hourly earnings of flour and grain-mill workers and to increases in price of supplies used by millers and bakers.

A study on margins and costs in marketing sweet corn shipped from the Belle Glade Area of Florida to Baltimore, Md., showed that 17.3 percent of the retail price went to farmers for production. The other 82.7 percent went for containers, picking and packing, shipping-point marketing charges, transportation, wholesaling, and retailing.

All these costs-and-margins reports have one characteristic in common. They're showing that marketing services cost money and account in some measure for the shrinkage of the percentage of the consumer's dollar received by farmers.

COOPERATION WITH STATE DEPARTMENTS OF AGRICULTURE

Although much of our long-time marketing service work has been done in cooperation with state departments of agriculture, a new type of federal-state marketing service work came into being with enactment of the Research and Marketing Act of 1946. This work constitutes a matched-funds program under which state departments of agriculture, with the cooperation of the Department, attack the major agricultural marketing service problems that confront the particular states. Projects proposed by the states are subject to approval by the U. S. Department of Agriculture.

The program has been divided into four broad categories: (a) maintaining product quality, (b) reducing costs and increasing operating efficiency, (c) expanding market outlets, and (d) collecting and disseminating basic data and local and nearby market information. Work in this program is highly varied. A few examples will indicate its scope.

Applegrowers in West Virginia were confronted with a serious price situation as the 1955 harvest season got under way. Although production was low, canners opened the season with a large carry-over of applesauce and offered only 80 cents a bushel for the new crop. As a means of stimulating apple sales to fresh fruit outlets and of improving grower prices, a clearinghouse service was initiated. Growers furnished daily information on the quantities, varieties, grades, sizes, and asking prices, and this information was passed on to truckers and other buyers, both at the clearinghouse and through bulletins and trade papers. The program increased growers' returns more than $500,000 and, by stimulating competition, raised the average price level for apples in the State by at least 30 cents a bushel.

In Louisiana, larger and better equipped cotton gins are rapidly replacing old, inefficient ones. During the 1955 ginning season, a specialist visited practically all the gins in the State to assist in the adjustment and operation of the new machinery. Assistance was also given in remodeling old gins and in planning construction of new ones. Considerable reduction in quantity of gin-damaged or "rough prep" cotton has been achieved since 1951, when the program was begun. Producers are averaging about $150,000 annually in increased income as a result of improved quality of their cotton.

A program was initiated in Colorado to assist producers and milk plants in improving the quality of milk and milk products. Surveys by marketing specialists revealed serious off-flavor and off-odor in milk produced on a number of farms in the Denver milkshed, as well as milk plant practices that tended to perpetuate the quality problem. To correct the situation, specialists, often accompanied by fieldmen from the dairy plants, visited over 250 farms in the Denver area to identify and help solve individual problems, and to train the fieldmen in quality improvement procedures so that the benefits of the program could be expanded and placed on a continuing basis.

Helping Farmers to Cooperate

Our story of what research has done and is doing to improve marketing would not be complete without some mention of cooperative marketing. The Department began work in this field in the early years of the century in connection with studies designed to improve the efficiency of fruit marketing. The first formal research project—cooperative handling and marketing of cotton—was begun in 1912.

When the Office of Markets was established in 1913, one of its principal responsibilities was to assist farmers in developing efficient cooperative associations. With the rapid growth of cooperatives after World War I, the demand for such assistance was recognized in various research studies. In 1926, the Congress further recognized the importance of this trend by passing the Cooperative Marketing Act, which set up a special division to provide research, advisory, and educational assistance for marketing and purchasing cooperatives. This work is now carried on in the Department by the Farmers Cooperative Service.

Many of the early co-ops failed because of shaky legal and fiscal foundations. Department research helped in both these fields. Some groups were advised how to proceed; others were advised not to proceed at all. Many of the young co-ops were having trouble with accounting procedures, and we were able to give them the kind of help they needed.

Many years ago some of the cooperatives figured that if farmers benefit from working together in a small co-op, groups of smaller associations should also benefit from a similar banding together. Because of its wide experience, the Department has been able to help in the development of many strong federations of cooperatives.

Further coordination of marketing by local cooperatives still is necessary in order to bring about the standardization of products, increased volume, more effective salesmanship and sales promotion, and to reduce marketing costs. Part of the current work with cotton, dairy, fruit and vegetable, grain, livestock, poultry, and other cooperatives is directed toward this problem.

Current emphasis is being placed on increasing efficiency of operations through operating economies in such fields as the marketing and distribution of feed, packing and processing of citrus fruits, operation of farmers' elevators and cotton gins, and marketing of poultry and eggs. As an outgrowth of the work with citrus fruits, an increasing number of packers are now handling fruit in bulk rather than in field boxes at a material saving in harvesting and handling costs.

Department research in cooperative purchasing of farm supplies has been closely related to that in cooperative marketing, because effective procurement of supplies is essential to efficient production and marketing. In fact, many farmers' cooperatives engage in both activities. Studies of cooperative purchasing date back to 1912, but its importance has greatly increased as the bill for such farm supplies as feed, petroleum, fertilizer, insecticides, farm equipment, farm machinery, containers, and other packaging material has increased with the mechanization and commercialization of agriculture.

EDUCATIONAL WORK IN MARKETING

Since its creation in 1914, the Extension Service has been the educational arm of the Department and the state extension services have carried on the off-campus educational work of the land-grant colleges. When this work began, the emphasis was almost entirely on production for the very good reason that most of the research was on production.

While some expansion in extension marketing took place in the 1920's and 1930's, the greatest expansion has taken place since passage of the Research and Marketing Act of 1946. There are now about 350 marketing specialists located either at state agricultural colleges or in marketing areas in addition to the work of county agricultural agents. Special emphasis is given to marketing information programs for consumers in metropolitan areas representing about half of our urban population, as well as with marketing firms, to increase efficiency. All this work is cooperative with the states. A few examples will illustrate progress to date.

In Delaware, an educational program was established to improve the quality of dressed poultry and increase marketing efficiency. A previous study had shown that between 7 and 17 percent of all poultry was bruised seriously enough to cause loss. Extension marketing specialists, working with producers and processors, demonstrated that greater care all along the line could cut this loss drastically. Many plants now report that they have reduced losses caused by bruises by at least 50 percent. Better consumer quality is also resulting from improved processing methods, better plant grading, and more accurate sizing. Processing costs are lower, and the margin between live and processed poultry has been cut perhaps as much as a cent a pound.

In the South, our marketing specialists are working with cotton manufacturers in improving methods and practices of processing and in manufacturing special end products to meet particular consumer needs. The use of the SRRL cotton opener, developed to "fluff up" cotton from bales and enable mills to clean it more efficiently, is a good example of this work. Latest estimates indicate that about 70 machines are now in operation, providing savings amounting to $10,000 per mill through reduced waste and improved processing.

Extension marketing specialists are working in most of the important fruit and vegetable producing states. In one Virginia county, for example, they helped in establishing a farmers' produce market, which is now handling more than $300,000 worth of produce. In New York, they helped onion growers shift to bulk handling and storage. Bulk storages have been built to take care of about one-third million bushels—at a savings of about 25 cents a bushel.

Early potato prices in Washington were very poor in 1955. Growers were greatly discouraged, and many were planning to reduce acreage. Outlook information on the potato situation was publicized through the press, radio, and college publications. As a result, Washington was the only Western state to increase acreage. Prices in 1956 were excellent, and the Washington early potato producers collected over $1 million.

The outlook and production program for lambs stresses producing for market in late April and early May when prices are seasonally high. Farmers in Kansas who followed the recommended program received $4 to $8 more than farmers who sold their lambs two to three weeks earlier or later. The timing of the production program in relation to outlook information has meant the difference between profit and loss to many farmers.

Marketing educational work is directed to city consumers as well as to producers, processors, handlers, and retailers. These programs have the double purpose of helping consumers choose economical foods for nourishing diets and at the same time helping producers to market foods that are abundant at the time. One method used in many states is to prepare buyers' guides on foods and give them wide dissemination through organizations, press, radio, television, and all other available means. Both consumers and producers benefit.

The future of our educational work is limited only by the rate at which we acquire new knowledge through research and by our own ingenuity and imagination in presenting this new knowledge to the people of the United States. They have demonstrated their faith in research. They have shown over and over again their willingness to accept new ideas and better practices. If efforts sometimes seem to be failing to get results, it is not the fault of those served; it is a challenge to all of us in research and education to do a better job.

CHAPTER VII

Research in the Medical Sciences

Harold Tager, Jr.

This is an attempt to define some of the directions of modern medical research. The emphasis, primarily, will be on scientific methodologies and only secondarily on scientific goals, at least insofar as goals relate to specific diseases. Such a definition of directions, of course, can have no finality, for directions are constantly changing in accordance with changes in the state of knowledge which obtain in a given area of research at any given time.

This approach may already suggest a greater complexity to medical science than is commonly understood. While it is difficult to state a general, static public view of medical research, it is probably safe to say that the public sees the goals of medical research as primarily being the control of disease. It is even more difficult to state a public view concerning the methodology of medical science, since methodology is a matter of little public concern. Yet such a view seems to exist in a general climate of feeling pertaining to all science—a view of science as orderly, progressive, predictable and leading to absolute conclusions.

This view, of course, does not really exist as a conscious public thesis. It might not be elicited by question or confirmed by confrontation. Nevertheless, it seems implicit in many ways. It is reflected by public interest in and respect for the scientific endeavor as manifested by the vast growth of public funds directed to the support of medical science. Both faith and hope are also reflected in the vast growth of medical research reporting in newspapers and magazines, behind whose factual façade lies the overt or implicit promise for the conquest of disease. It exists in the language and images surrounding the scientific endeavor, for words such as "miracle," "mystery," "probing" and "attacking" connote a power larger than life, just as does the persistent, inaccurate image of the scientist working alone in the laboratory at night. And most important of all, perhaps, the view of scientific infallibility seems to be confirmed by the public's willingness to accept and adopt even the most preliminary findings of science (especially the behavioral sciences) so that there is increased concern (on the part of sociologists and poets, at least) that science has subverted the individual will, and science has led to the erosion of standards for which science can offer no substitute.

There are probably a large number of reasons which would account for the authoritative position of science in the public eye. Some of the reasons obviously rest with the nature of science itself and its necessary insistence on measurement, classification, evidence and validation—standards which have come to represent the determinants for truth in even nonscientific fields. The technical esoterica of science and the removal of the scientist, thereby, from mass communication has also been a factor in creating a mythology of science, though this mythology would not be a favorable one if science did not at the same time offer a view of bright vistas—a future free of premature death and disability, and a life both fruitful and pleasant. All these and many other factors, however, would certainly not be significant were it not for the extraordinary success of medical science, which since the end of the 19th century has created a climate of authority for medical science and has established the medical scientist as public hero.

Men of science have also contributed directly to the views of scientific authority. Today, it is true, probably few scientists would claim the total infallibility of science, yet it is no more than half a century ago that there was strong debate as to whether science would not displace theology and philosophy—and only recently, indeed, has theological and philosophical thought begun to reassume its importance. Similarly, while few scientists today would care or dare to predict the conquest of a specific disease, this was not so even two generations ago. It was in 1910, after all, 35 years before the evolution of the poliomyelitis vaccine, that Simon Flexner of the Rockefeller Institute succeeded in passing the poliomyelitis virus from one monkey to another and confidently said: "Now the question of a vaccine to control this disease is but a matter of months."

It is easy to laugh at Dr. Flexner's presumptuousness today. It is well to remember, however, that Flexner was a distinguished scientist, and it may cast some light on directions in modern medical research to examine the nature of his error. In brief, it probably would be fair to say that Flexner stood at one of those crossroads in medical science where changes in the problems facing medical science quite unexpectedly invalidated expectations which should have been reasonable. Flexner's prediction, in short, regarding a virus disease—poliomyelitis—was probably based on experience and knowledge related to the bacterial diseases, where his success might have seemed central to the development of a vaccine.

Flexner's error is suggestive, moreover. It suggests that the present public view of scientific omniscience may be largely based on experience which was essentially true for the end of the 19th century and the beginning of the 20th. The rapidity of scientific advances at this time was, in fact, truly extraordinary, and for the scientist then, and for the public then and now, must have held out promise of scientific authority in the relatively near future for the complete conquest of disease. In this regard it is probably noteworthy that the present public images of scientific authority are men long dead—men such as Pasteur, Jenner, Lister, Ehrlich and Koch. Only Jonas Salk represents the possible exception.

This should not imply that men of great scientific stature do not exist today. Men of scientific genius exist in plenitude, but their contributions, unlike the contributions of the past, are likely to seem small in the public eye. In most instances the major scientific finding of today simply seems to represent one technical incident in the long course of events which finally culminate in the conquest of disease. Dr. Salk's contribution itself, as Salk himself has often protested, was simply the final one in a series of contributions made over a period of 50 years. Because it was the final one, because the quest for the poliomyelitis vaccine had become a public crusade, it was natural that Salk should be appointed the hero.

The long history of the development of poliomyelitis vaccine carries the obvious implication that science today is more complicated than the science of yesterday. This is true to a large extent (if only to the extent that the body of scientific knowledge has grown enormously), and it is largely these complications which have changed the nature of modern medical science. It is for this reason that a brief review of some of the problems surrounding the development of the poliomyelitis vaccine is being provided here.

John Paul of Yale University pointed to some of these problems in 1952 when he wrote:

> A disease originally regarded as limited to infants is no longer confined to infancy; a disease originally considered mildly contagious is now regarded as almost as contagious as measles; a disease in which the clinical picture was originally thought to be limited to acute paralysis is now regarded as a disease in which only 1 in 100 or more of those infected become paralyzed . . . and from an endemic disease, it has tended to become epidemic; from a curiosity, it has become a common and periodic scourge.

Dr. Paul's statement indicates only a few of the epidemiological complications which faced the poliomyelitis vaccine research effort since poliomyelitis was first identified as a distinct disease entity at the beginning of the 20th century. There were many others, however, and a number of them stemmed from the fact that bacteria were visible under the microscope and that viruses were not. One of the major questions facing early investigators, for example, was: How can the specificity of the poliomyelitis organism be established, especially as the lesions it causes in the central nervous system are similar to lesions caused by other organisms?

The development of blood tests for the identification of viruses eventually was to provide the answer. But as one answer emerged, so did another question. Gathering evidence was soon to indicate that there was not one poliomyelitis virus but many of them of varying virulence. How could a practical vaccine be developed incorporating almost 200 different organisms? The problem was only to be resolved when it was discovered that all strains could be grouped under three fundamental types. Behind this discovery, however, lay 30 years of research on related problems: on the adaptation of poliomyelitis viruses to small animals, on the adaptation of serological methods for the identification of viruses; and on the development of methods for virus purification.

There were other problems in the development of the poliomyelitis vaccine. A vaccine confers protection because the "killed" or "attenuated" virus in the vaccine stimulates the formation of *antibodies in the blood* which oppose the action of the virus. But there was no evidence that the poliomyelitis virus entered the blood stream. All the evidence seemed to indicate that the viruses entered the body through the mouth and intestinal tract, then made their way along the nerve fibers to attack the critical nerve cells in the central nervous system, bypassing the blood stream entirely. At what site of the body, then, could a potential vaccine be injected to provide protection? In 1952 the answer was finally obtained when scientists were able to recover poliomyelitis virus from the blood of monkeys and chimpanzees three to five days after they had been infected. The virus did enter the blood stream, although usually for not more than 24 to 36 hours.

It was, in fact, at this point that the practical development of a vaccine became theoretically possible. It would not have been possible, however, if a method had not already been defined for growing poliomyelitis virus in quantity. Viruses, unlike bacteria, do not multiply by themselves; they multiply only in living tissue—moreover, only in certain tissues for which they have specificity. Because the poliomyelitis virus was specific for the central nervous system, viruses were first grown in nerve tissue—inside animals—and then as methods were found for keeping tissue alive when excised from the animal—inside test tubes. But the possibilities for developing a vaccine cultured from such nerve tissue medium was remote. The nerve tissue could not be entirely separated from the virus, and the residual nerve tissue in a vaccine could cause encephalitis, a disease of the nervous system as serious as poliomyelitis. So it was that when a method was devised for growing poliomyelitis virus on monkey kidney tissue, a major problem in future mass vaccine production had been resolved.

The evolution of this procedure was not simple. Indeed, a full review of this finding and other findings mentioned here in passing would reveal a long sequence of trials and errors, successes and failures on the part of many scientists working in many different countries. This is to say that while a telescoped history of the poliomyelitis vaccine seems to indicate a continuity of effort directed towards its achievement, that history, in fact, was actually composed of a number of shorter histories, some of which at the time they were enacted might have seemed to have only fortuitous relevance to the development of the poliomyelitis vaccine.

This question of relevance is important in the examination of both the goals and methodologies of medical science. Let us look at the development of tissue culture as a medium for the growth of poliomyelitis virus, a discovery which won the Nobel Prize for John Enders and his colleagues at Harvard, a discovery, therefore, generally acknowledged by scientists to be the most important single contribution to the evolution of the poliomyelitis vaccine. What is important to note here is that while Dr. Enders was aware of the significance of his findings as a practical tool, his findings emerged as the result of a long interest in the cultivation of all viruses, especially the influenza and mumps viruses. Moreover, this interest in virus cultivation and, indeed, the interest of many before him who made his work possible was not primarily in a vaccine or vaccines but in the creation of a technique which would permit closer observation of virus action in relation to the host cell, leading, perhaps, to a more basic understanding of virus reproduction, virus nutrition and even virus structure.

It is probably safe to say that the problems of virus reproduction, virus nutrition and virus structure presently command as much or more research attention as the practical development of virus vaccines. Much medical science today (not by any means in absolute contrast to yesterday) is not motivated by resolving the problems of disease but is directed towards resolution of problems of general biological interest. This is no luxury, however, for as we have already observed in the development of tissue culture, this motivation may be fortuitously practical—how practical, indeed, cannot yet be determined. Even now tissue culture is advancing work on the development of other vaccines, is advancing work on the discovery of new viruses and their correlation with specific clinical conditions whose causation was hitherto unknown, and finally it is advancing the study of cellular growth and nutrition, including the growth and nutrition of cancer cells.

This should not intimate, however, that studies directed to understanding general biological facts and studies directed to the development of practical measures against disease are necessarily so intimate. The time interval which can exist prior to the forging of the link between what is called fundamental and basic research may be very short or very long, for it depends not only on the historical opportunity for making the synthesis (just as tissue culture had to await the classification of poliomyelitis viruses before a poliomyelitis vaccine became theoretically practical), but it also depends on the presence of the scientists capable of making the synthesis when the time is ready for it. Indeed, it seems likely that some findings in the fundamental biological sciences may never be applicable to disease either directly or indirectly, but will exist in themselves as pure data, roughly comparable to a historical footnote.

In this light, the continuity of medical science as seen by the public in relation to the conquest of disease may seem to be very haphazard indeed. What seems to have been said in effect is this: that medical science is loosely the totality of all the efforts of individual scientists in the biological sciences who have the freedom to choose the direction of their investigations and within that freedom are guided in their choices as are other men—by interest, ability, training and even ambition and opportunism. Within this freedom, then, one scientist will wish to investigate the relations of cigarette smoking to lung cancer while another will choose to investigate the chemical structure of the cell.

If the word science now seems to lose its sense of authoritative solidity for being simply seen as the arbitrary sum of the diverse efforts of many men, this should not obscure its very real, inherent character. Insofar as the mission of scientists is the accumulation of new knowledge about biology, and its building blocks must be old knowledge, science is naturally progressive and dynamic, more so, indeed, than any other area of human endeavor. Nor is this developmental process quite so random as it sounds: few scientists really see their work as simply one more stepping stone in a series of stepping stones leading to nowhere (or somewhere only by accident) but hope to relate their work to some larger systematic pattern of natural phenomena.

The persistence of the virus theory of cancer, for example, is a notable case in point. It is one of a number of unproved theories concerning cancer causation but it reveals more clearly than most that interplay between experimentation and idea which ideally is said to characterize the medical research effort.

As early as 1903, the virus etiology of cancer was suggested. It was just suggestion, and it was rejected. Skepticism continued, however, even when in 1911 it was demonstrated that a sarcoma of the breast muscles of a hen could be transmitted by a filterable cell-free extract of a tumor. This evidence and even the considerable body of later evidence indicating that viruses were associated with a variety of cancerous growths in domestic and wild animals could not counteract the fact that it was impossible to demonstrate after continued effort that viruses were responsible for tumors and cancers in man.

It is still impossible to make this demonstration, but increased knowledge concerning viruses has kept the virus theory of cancer alive. Some scientists point out that the action of certain viruses is completely compatible with the presence of cancer. For example, the stimulation of cell growth characteristic of cancer is a stimulus frequently caused by viruses prior to causing cell destruction. The fact that cancer arises in varying bodily sites is explicable by the fact that viruses are capable of infinite mutation. And it is claimed that the appearance of cancer among all age groups is compatible with the existence of viruses which remain latent in bodily tissue from infancy to later life.

Many attempts have been made to explain why viruses are not found in human tumors. One theory that the virus is "masked" in human cancer has received some experimental support, but the "masking" mechanism has never been elucidated though scientists have tried. It was more than 20 years ago, for example, that a virus was extracted from papillomas of cotton-tail rabbits and transmitted to other rabbits. While the virus caused papillomas on transmission, no virus could be obtained from them, in spite of the fact that neutralizing antibodies in the blood stream gave evidence of their presence. This was 20 years ago, however, and while this "masking" effect has been duplicated in animals, no indication that cancer in humans is due to a nonisolatable virus really exists.

Proponents of the virus theory of cancer now look to further definitions concerning viruses in their relationship to genes as a source of chief support for their theory. There is, for example, some evidence that some viruses resemble genes in their multiplication, aberration and in their nucleoprotein structure. One analogy between the "living" virus and the "nonliving" gene in terms of chemical structure was strengthened this past year when investigators at the University of California succeeded in reconstituting a virus by chemical means, apparently supporting Wendell Stanley's thesis that the "virus might be placed at the boundary of the living and the nonliving, if in fact that boundary could be said to exist." This finding may be said to lend partial support to the theory that tumor viruses (as distinct from other viruses) may be formed under certain circumstances from normal components of the cells cytoplasm and that such alteration can be permanent and be transmitted in the cytoplasm.

Other experimental findings also lend some credence to this view. It has been found, for example, that one type of gene, called the plasmagene, which is present with other plasmagenes in the cytoplasm of the unicellular Paramecium, is capable of killing other strains of Paramecium. This Kappa factor is passed from generation to generation in cell division, resembling the gene in its power of reproduction, though unlike the gene, Kappa factor multiplies within the cell, as does the virus, independently of cell division. Other experimental findings might also be interpreted to indicate that plant viruses arise in the course of cellular metabolism from normal mitochondria (particulate bodies in the cytoplasm) or from their derivatives, the plastids (comparable to the plasmagenes of animals cells).

At this point it would be well to emphasize again that the virus theory of cancer is only one of a number of theories of cancer causation. To call it a theory, in fact, would suggest that it provides in itself a strong stimulus to research calculated to support that theory (in the same sense as theory has become basic to making practical developments in the physical sciences). This is not so, however, for the state of the biological sciences is such that the main methodology is from the particular to the general, the theory emerging tentatively as a result of the correlation and synthesis of data and constantly subject to change or correction. It is probably safe to say that knowledge of the complexities of the living organism is so young that formulation of accurate predictions on a broad scale will be impossible for some time to come.

The virus theory of cancer, therefore, is based on a diffuse body of data drawn from various fields of investigation. Apart from applied research (such as the determination of carcinogenic agents or the testing of anticarcinogenic chemicals) a large part of what is called cancer research exhibits this diversity and is essentially called cancer research only for purposes of public communication. All investigations of the growth, activity and nutrition of the cell might well be considered research on cancer, for example, and so might a large proportion of research in protein or enzyme chemistry, though such research might ultimately prove to be as applicable to other diseases as well.

The degree to which research on a "disease" will tend to be more or less diverse or more or less directed to "fundamental" problems of biology depends in part on the state of knowledge concerning that disease. Research on poliomyelitis, for example, tended to exhibit relatively close focus and continuity, for once the cause was known (the poliomyelitis virus), the direction to the goal (a poliomyelitis vaccine) could be set in motion. In research on cancer and the other chronic diseases (heart and mental diseases, neurological and metabolic diseases), where the cause or causes are still unknown, the approaches obviously must be broader. This is not to say that the scientific attack will not have a focus: the cell is the major focus in cancer research, yet it should be remembered that the boundaries of research on the cell are so broad as to almost include study of all aspects of the total bodily organism.

The state of knowledge governing the research focus varies from chronic disease to chronic disease, and some diseases have yet to yield to science enough information for science to find any focus whatsoever. This is in large part true for schizophrenia, where up to the present time science has found it exceedingly difficult to even formulate the kind of problems which might best be undertaken. A major difficulty here lies in the fact that it cannot yet be determined whether schizophrenia is an organic or inorganic disease: indeed, since the disease is identified by its symptoms (not its pathology) and because the symptoms are behavioral, in which the "normal" (as a normal cell) is not readily definable, schizophrenia is not entirely recognizable as a distinct disease entity.

Insofar as schizophrenia may most logically be associated with some specific dysfunction of the brain, broad studies on the functioning of the brain may hold the chief hope for obtaining some first footholds on the problem (though it is still possible that socio-environmental or psychoanalytically oriented research may cast further light on the question than hitherto). Organic studies of the brain relating to behavior presently face extraordinary problems, however: neither the brain nor behavior of animals can be closely correlated with the brain and behavior of man, so that research on the animal brain tends to be not as useful as it is, say, on the animal cell. The living human brain, moreover, is not readily accessible for observation organically and even indeed psychologically, though the possible development of new methodologies and new instrumentation may promise some help in this kind of research for the future.

One course of research which may throw light on the schizophrenic process may emerge from further examination of the new tranquilizing drugs (most of them derivatives of reserpine and chloropromazine, first utilized as hypertensives). Elucidation of the nature of their action i.e. on what area of the brain they act and by what chemistry they effect their action, may lead to a definition of those organic abnormalities responsible for certain mental and behavioral disorders and finally to methods of treatment and prevention more specific and direct than those presently utilized. Elucidation of a drug's activity, however, may well entail a complex series of investigations which may prove unproductive even after a long period of time. This is to say that a drug will interact or be acted upon by so many physical and chemical properties of the body as to make it impossible to determine which factor is central to the drug's effect on disease. Though insulin, for example, has afforded adequate control of diabetes for nearly a half century, continued effort has not yet elucidated the fundamental mechanisms of its action or illuminated the causes of diabetes.

At this point it may be interesting to note that the public generally views the drugs now available for the treatment of disease as almost final or absolute in their effectiveness. This status accorded modern pharmaceuticals probably reflects the authoritative status of the physician who dispenses them. While most drugs (as prescribed or administered by a qualified physician) are unquestionably useful, their usefulness is limited: this is to say that few if any drugs may be said to be so specific for a disease as to make it beneficial for all those subject to that disease. The fact that each year witnesses the marketing of new substitutes for drugs already on the market—new antibiotics, for example, new anti-arthritics or new tranquilizers—is an expression of the need for extending the range of therapy and/or for eliminating the side effects which so frequently accompany drug administration.

The lack of specificity of most drugs is probably due largely to their mode of development. Most drugs emerge as a result of "trial and error" (though this procedure is more complex and sophisticated than it sounds). This is to say that a drug will emerge as therapy for a disease as a result of its observed effects on symptoms rather than (ideally) as an agent constructed for its predictable effects on all the known biological factors (physiological and chemical) which may play their role in that disease. Most drugs, in short, have evolved as therapies for disease before the mechanisms of that disease were elucidated, and it seems likely that this kind of evolution will continue for some time to come.

If this is so, it is only fair to ask why there should not be an intensification of effort devoted to the development of drugs for those disorders for which there is presently little or no treatment. The considerations of this chapter up to now have not made it clear, but the fact is that a very large proportion of the nation's medical research effort is dedicated to drug development and drug testing. It is the major effort of the pharmaceutical industry; it is of interest to many clinicians in hospitals and medical schools; and increasingly the federal government has come to sponsor such research, especially where the outlay of large sums of money may not seem warranted to the pharmaceutical industry in terms of immediate return.

There are, however, a number of limitations on how much of such applied research may be undertaken. One major limitation may be the state of basic research, for in part the number and kinds of drugs available are determined by fundamental knowledge relating to the structure of chemicals (natural or synthetic), to methods of synthesis, extraction (from the soil, animals and plants) and purification. The possible relationship of a chemical to disease, moreover, (a factor which may determine whether or not it is tested) will depend in part not only on some knowledge of abnormal chemistry of that disease but also on knowledge of the normal chemistry of the body (likewise affected by a drug or chemical). This is to say that "trial and error" in drug development is not random; and such a decision as was made two years ago by the federal government to support a broad program of research in the chemotherapy of cancer was contingent on the accumulation of knowledge derived over a period of two decades.

There are other limitations to undertaking large programs in applied research. Those programs are extremely expensive, and they draw heavily on research manpower and research facilities. Where the promise of practical achievement is great, of course, these limitations may be considered invalid, but a large number of scientists are beginning to feel that much applied research is being initiated without realistic regard of opportunity, largely as a result of increased public participation in the medical research effort and consequent public pressures. These scientists, moreover, are not entirely concerned with the increasing volume of applied research as a problem in itself but with that volume as it may be a reflection of neglect for fundamental research.

There is probably little question that applied research has grown steadily during the past decade. It has been marked by the rapid rise of the voluntary health agencies whose obligations to applied research were inherent in their creation by special public interests (that of patients or relatives of patients) and by their support from a public fearful of specific diseases or sympathetic to its victims. Since federal support of research is fundamentally dependent on the same interests, applied research has tended to receive increased support from this source, although it must be acknowledged that Congress has shown a constantly deeper understanding of the needs for fundamental research (the understanding, however, contingent on the probable, ultimate application of such research to the problems of disease).

In spite of an apparent emphasis on developmental research, what is apparent in reviewing the growth of all medical research during the past decade is that enough funds have become available so that fundamental as well as applied research can receive sufficient support. The past decade has seen the medical research effort rise from less than $50 million to more than $300 million, largely as a result of increased government appropriations for this purpose. The Congress in making these appropriations has relied heavily on scientific counsel from both within and without the government, and while earmarking research funds in deference to majority public interest (the National Cancer and Heart Institutes, for example, receive the largest appropriations of the seven National Institutes of Health), has permitted these funds to be used with discrete flexibility by scientific administrators oriented to the needs of fundamental research (as well as applied).

The fears then of fundamental scientists concerning the neglect of fundamental research (and they are strong) are somewhat difficult to understand; even more difficult in view of the increasing sensitivity with which public funds have been administered to meet the special needs of basic scientists—the needs for research security (relatively speaking) and the needs for freedom of research action (absolutely speaking). These needs in the first instance relate to the basic researcher's opportunity to pursue a course of investigation whose limits in time cannot be defined, and in the second instance relate to the basic researcher's opportunity to pursue a course of investigation as the course may logically and inevitably take him, even if it deviates radically from his original plan. (In essence, the outline for a scientific experiment can only have the relative stability of an outline for a novel, for once the work is under way new insights may come to create new values and eliminate old ones.)

The degree to which both of these needs for fundamental research are being met is not entirely measurable. It is significant, however, that grants made by the National Institutes of Health to universities and other institutions (representing approximately one-third of the national medical research effort) are being made for longer periods than ever before, the average duration of support for a grant in 1957 being 3.2 years as contrasted with 1.8 years in 1951. While grant applications must present a relatively detailed plan of an investigator's research intentions, once the grant is made an investigator is free to violate that plan or even to discard it; and while an investigator must present a periodic progress report after the second year, what really counts in determining further support is the final nature of his contribution (as determined by his scientific peers).

In spite of the fact that fundamental research is receiving overt, conscious support at a level which never before obtained in this country, as already suggested, the basic scientist apparently feels both threatened and hostile. This is marked not only by his continued insistence on the neglect of fundamental science (apart from obvious needs for more basic research), but through a number of other manifestations. It is marked, for example, by the sharp, even contemptuous, distinction basic scientists are likely to make between their work and the work of applied scientists. It is marked by the unwillingness of the basic scientist to clarify the nature of his efforts to the public, on the grounds that the public press presents a distorted picture of those efforts. While valid in many respects, this attitude reflects a defensive preciosity—for if the basic scientist claims that his work can only be judged by another basic scientist (as he does), his attitude to public media should logically be either indifference or amusement, for presumably the public does not make the judgments that really count. But the public, of course, does count.

The complex and technical nature of fundamental science is such as to remove the basic scientist from the usual avenues of social communication. The resulting sense of isolation is certainly mitigated in part by the scientist's enjoyment of the society of his peers, but insofar as this society draws closer and closer (the scientific meeting is becoming more and more common), it must come to reflect a kind of collective inbred isolation.

This problem receives some attention here as one consideration in viewing the future of medical research in America. Superficially it might seem that all the environmental elements which would favor the flourishing of American medical science are at hand. It seems likely, for example, that sufficient funds for the support of medical research will continue to be available, that, similarly, sufficient funds for the support and expansion of medical research and medical research facilities will also be forthcoming. While there will be continued pressure for "practical" or "applied" research, these pressures will be met by the organized elements concerned, and the opportunities for fundamental research will also be realized.

How and if the internal pressures on the scientist will significantly change, however, is less predictable. This question may have some significance, partially in terms of the possible deleterious effect of that pressure on research productivity and on causing a deviation in research goals and partially in terms of the indirect effect of that pressure on recruitment of new generations of fundamental scientists, a more measurable problem and one of considerable importance.

The problem of public pressure, as suggested, can be a serious one, but will probably only be solved by history. This is to say that if science succeeds in its attack on disease (and success in the public eye may possibly be assured through improvements of many available methods of treatment and prevention), then, of course, there is no problem at all. If on the other hand, the conquest of the chronic diseases (especially heart and mental disease) is delayed beyond the relatively immediate future, the pressure will, of course, be contained by events—though the main issue then would be the possibility of the public withdrawing support from medical science. This support, however, now seems so solidified that such a contingency seems highly unlikely and the continuity of medical science on the same broad scale seems well assured for the future.

CHAPTER VIII

Applied Atomic Energy Research

GERALD L. HUTTON

INTRODUCTION

DEVELOPMENT of atomic energy in the past decade has resulted in far reaching and momentous socio-economic implications of such magnitude and diversity as to challenge realistic appraisal at this time. Atomic energy (more properly "nuclear energy") resulting from fissioning or splitting of the atom is more than a promise. Mankind has already reaped many benefits from this potent force. Many technological problems must be solved, however, before the full potential of this tremendous source of energy can be realized.

The concept that all matter is comprised of atoms can be traced to the early writings of Greek, Roman, and Hindu scholars, Democritus (about 460 B.C.) in particular. As a result of Aristotle's opposition this hypothesis was abandoned for a number of centuries to be revived later by René Descartes, Francis Bacon, Isaac Newton and their contemporaries. John Dalton, English schoolteacher, is generally credited with originating the modern concept of atomic structure. It appears that his views were not entirely original, but were based on hypotheses expounded by Isaac Newton and other scientists.

Realization of atomic energy, as with most significant discoveries and developments, depended upon a multitude of other collateral postulates, theories, and findings. Some of the highlights in the development of applied atomic energy may be noted: the discovery of radioactivity by Henri Becquerel in 1896; invention of the original Geiger counter by E. Rutherford and Hans Geiger in 1908; Niels Bohr's concept in 1913 of the atom as a nucleus surrounded by empty space; the achievement of artificial transmutation of an element by E. Rutherford in 1919; identification of the neutron by J. Chadwick in 1932; discovery of artificial radioactivity by F. and Irène Joliot-Curie in 1933; discovery of nuclear fission by Otto Hahn and F. Strassmann in 1939; construction of the first successful nuclear reactor by E. Fermi, and others, in 1942. The work of many other scientists, such as H. Von Halban, L. Kowarski, and J. R. Oppenheimer, contributed to important steps in the development of atomic energy.

On December 2, 1942, the first nuclear reactor or atomic pile, (See Figure 1 in pictorial insert following page 134.) consisting of graphite blocks interspersed with lumps of uranium was placed in operation at the University of Chicago. Rudimentary in construction, this initial reactor was an important milestone in man's endeavor to release the tremendous energy locked within the atom.

Atomic Energy in Brief

All matter is comprised of atoms. An atom may be defined as the smallest particle of an element capable of entering into a chemical reaction. More than a billion atoms could be placed on the head of a pin. An atom, however, is in turn composed of much smaller components. These constituents include a central nucleus (composed of protons and neutrons) which has a positive electrical charge. The nucleus is surrounded by electrons with negative electrical charges which collectively neutralize the positive charge of the nucleus. The atom, consequently, is electrically neutral.

In many respects the atom is analogous to our solar system, the nucleus representing the sun and electrons corresponding to the planets. The mechanical laws governing movement of planets and electrons, however, are different and the analogy fails. The component parts of the atom are bound by strong forces. Some atoms are unstable or "radioactive," the nucleus emitting radiation which may be either minute particles or a quantity of energy that moves in a wave. Radioactive atoms may occur in nature (e.g. radium) or be produced artificially.

If the nucleus of certain atoms (such as uranium 235 atom) is penetrated and stimulated by a neutron, the nucleus breaks into two main portions and ejects several neutrons. The main fragments and ejected neutrons rush from the point of fission at high speed. A great release of energy in the from of heat occurs concomitant with the splitting or disintegration of the atomic nucleus. This is "atomic energy." A nuclear chain reaction results if the liberated neutrons split other atoms resulting in ejection of additional neutrons which in turn penetrate and excite other nuclei, etc. (See Figure 2, What a Chain Reaction Is, found on page 136.)

There are four primary types of ionizing radiation of immediate interest:

1. *Alpha radiation* is composed of particles, each of which has two protons, two neutrons, and carries two positive electrical charges. The alpha particle is a relatively large particle and it has a low penetrating power. Most alpha par-

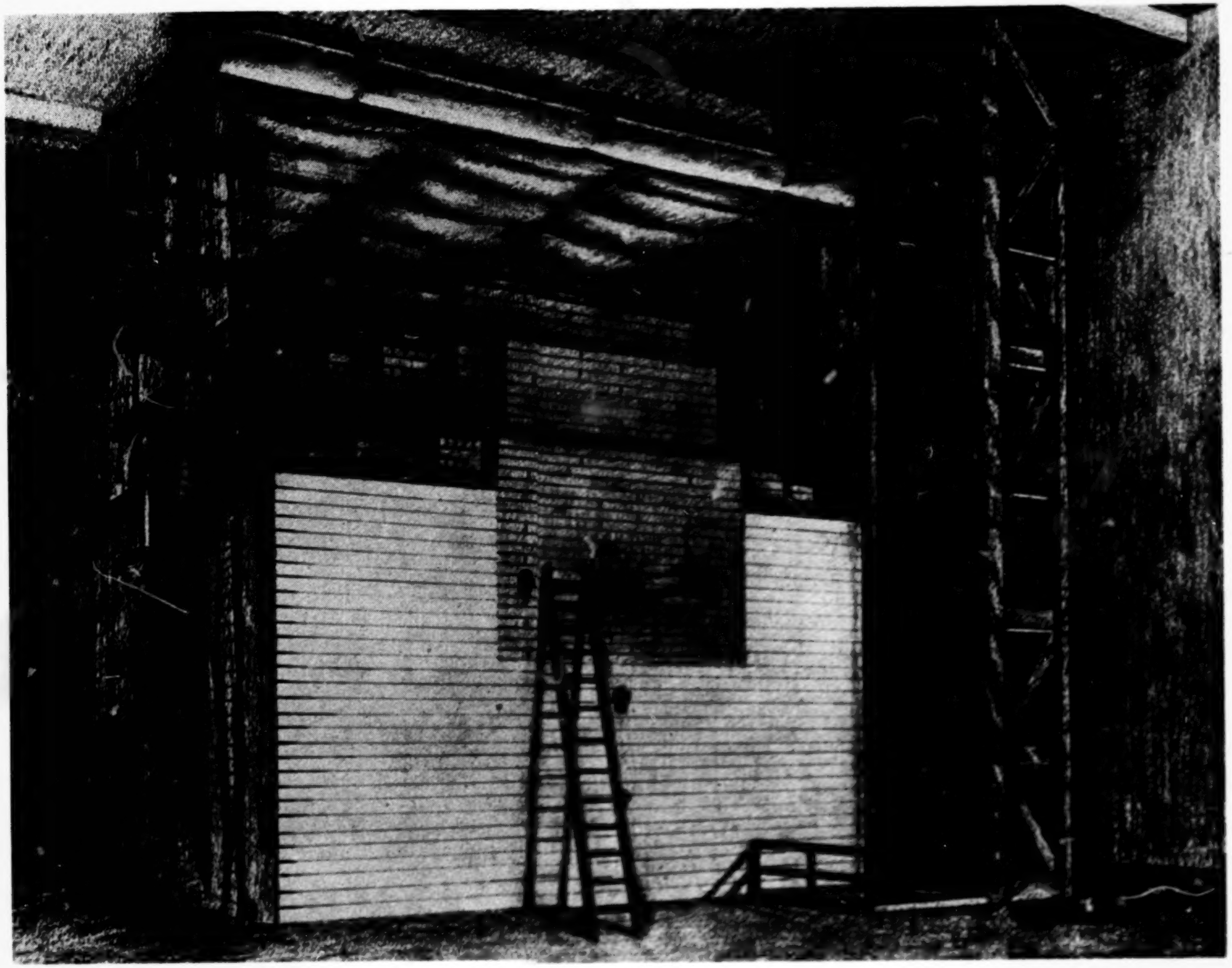
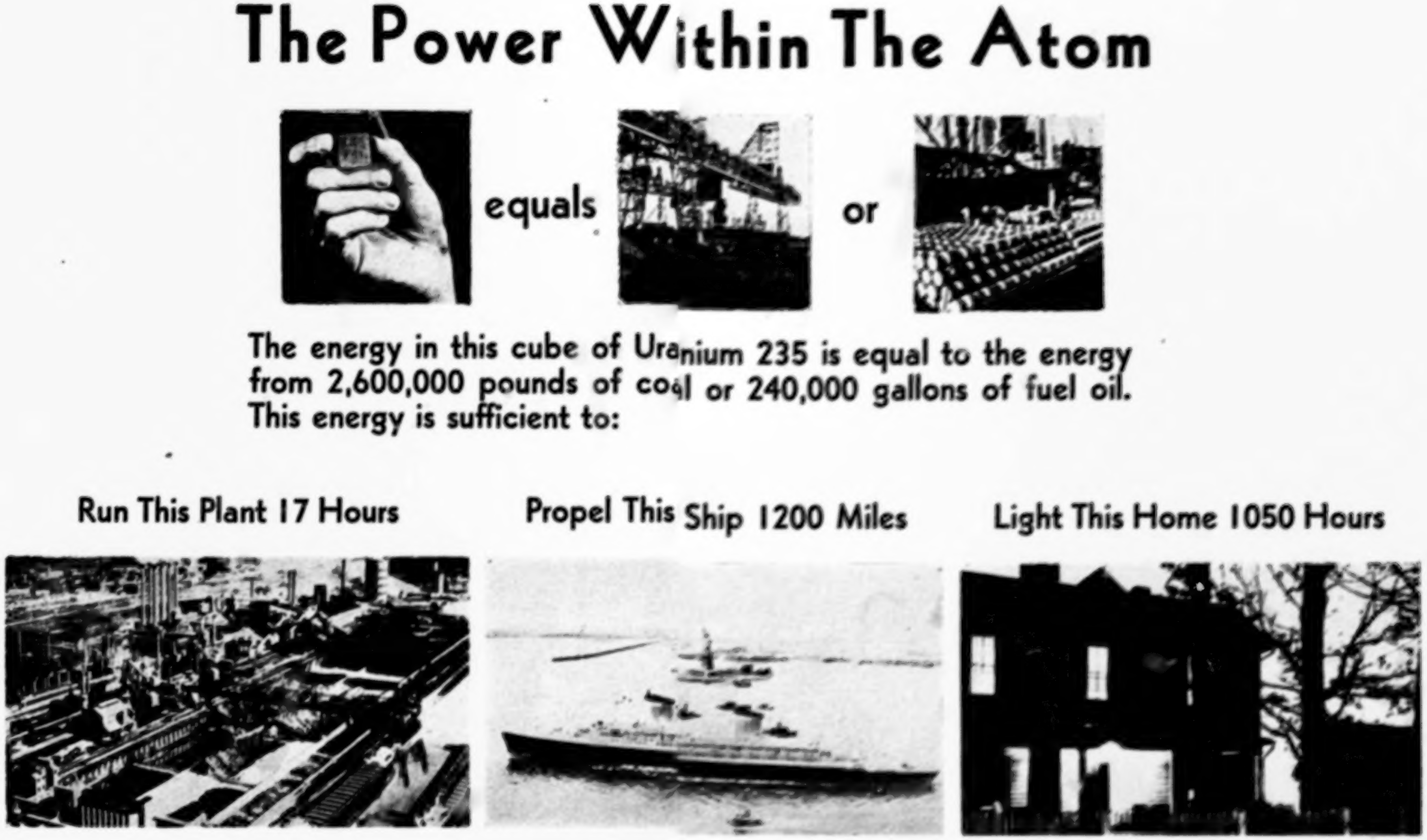


FIGURE 1. DIAGRAM OF THE FIRST ATOMIC PILE, STAGG FIELD, UNIVERSITY OF CHICAGO



The Power Within The Atom

equals
or

The energy in this cube of Uranium 235 is equal to the energy from 2,600,000 pounds of coal or 240,000 gallons of fuel oil. This energy is sufficient to:

Run This Plant 17 Hours
Propel This Ship 1200 Miles
Light This Home 1050 Hours

Figure 12

ticles are easily stopped by a thick sheet of paper or the external layer of skin on the body.

2. *Beta radiation* also consists of particles. These are electrons, each with one negative electrical charge. Since these particles are smaller than alpha particles, their penetrating power ordinarily is greater than that of the alpha particle. Beta particles penetrate a fraction of an inch into animal tissue.

3. *Gamma rays* are energy waves, similar to the familiar X rays, and have similar characteristics of deep penetration into matter. High density materials, such as lead and concrete, are frequently used to reduce gamma rays to harmless levels.

4. *Neutrons* are particulate ionizing radiation, have no electrical charge, and are capable of deep penetration into matter with little energy loss. Neutrons of an atom may render such target atom radioactive. Thus, materials exposed to neutrons may become radioactive and emit ionizing radiation.

PRACTICAL BENEFITS OF ATOMIC ENERGY

An understanding of nuclear physics or the fundamentals of atomic energy is not an indispensable prerequisite to an appreciation of what atomic energy can do and is doing for mankind. The value of the airplane is obvious to essentially all persons, most of whom have little or no knowledge of aerodynamics. An understanding and appreciation of the utilitarian aspects of atomic energy is also possible if emphasis is placed on "what" rather than "why."

A nuclear reactor, of which there are many types, produces radioactive materials which may be distributed and used apart from the reactor proper; emits ionizing radiation that may be used directly for research and other purposes and generates heat that may be converted to electric power or used for other purposes.

RADIOISOTOPES

Operation of a nuclear reactor results in production of fission products some of which can be economically separated and distributed as radioactive isotopes (radioisotopes). Materials can be placed in a reactor and subjected to neutron bombardment thereby creating other radioactive isotopes. It is possible that these "radioisotopes," byproducts of reactor operation, may prove to be the most important contribution of atomic energy to mankind.

A radioisotope of an element may be defined as a form of an element with identical chemical properties as other forms of the element but having a different atomic weight and emitting ionizing radiation. Radium is a well-known example of a radioisotope which occurs in nature.

Prior to the development of nuclear reactors only limited quantities

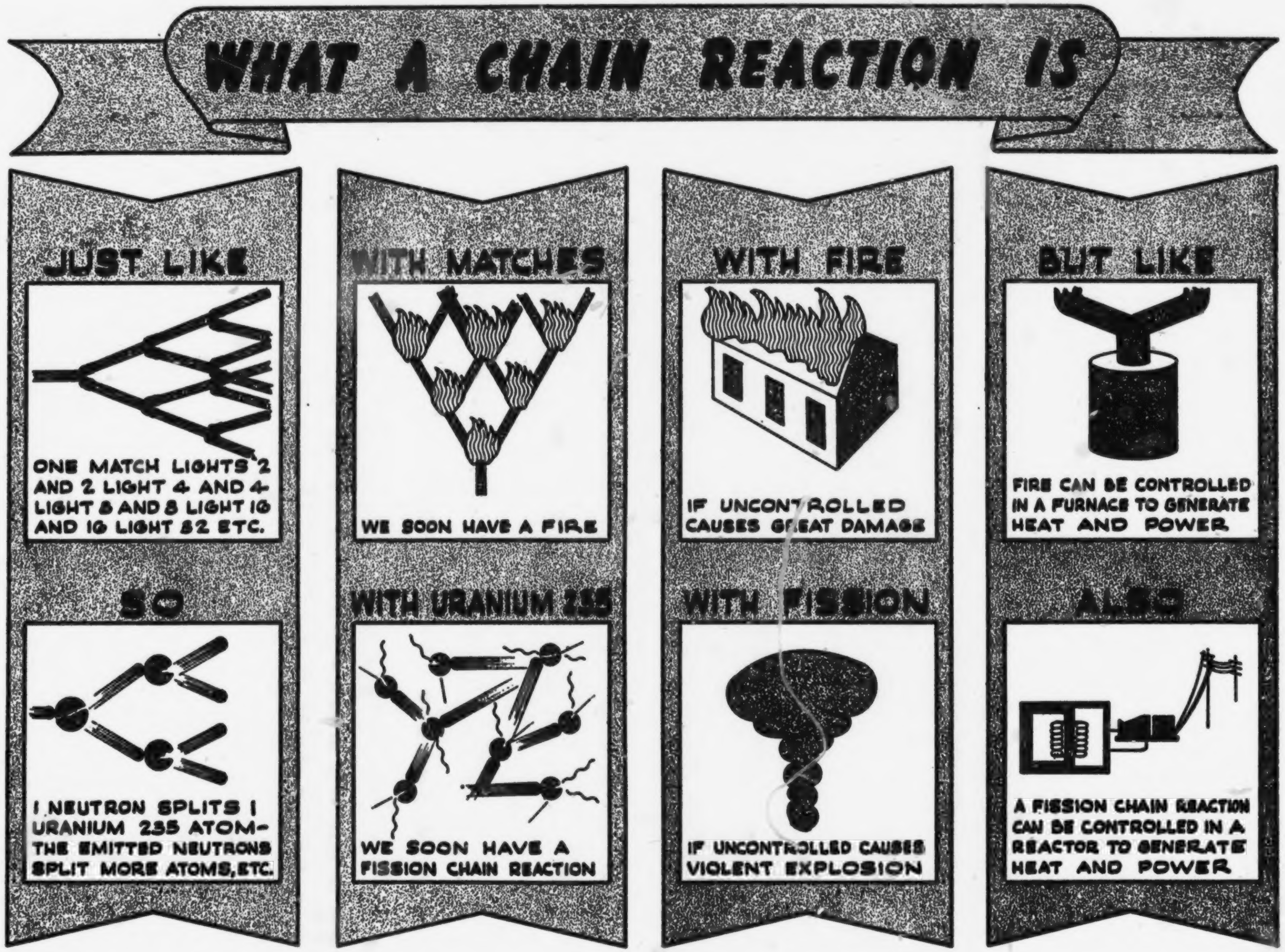

WHAT A CHAIN REACTION IS
JUST LIKE
ONE MATCH LIGHTS 2 AND 2 LIGHT 4 AND 4 LIGHT 8 AND 8 LIGHT 16 AND 16 LIGHT 32 ETC.
SO
1 NEUTRON SPLITS 1 URANIUM 235 ATOM-THE EMITTED NEUTRONS SPLIT MORE ATOMS, ETC.
WITH MATCHES
WE SOON HAVE A FIRE
WITH URANIUM 235
WE SOON HAVE A FISSION CHAIN REACTION
WITH FIRE
IF UNCONTROLLED CAUSES GREAT DAMAGE
WITH FISSION
IF UNCONTROLLED CAUSES VIOLENT EXPLOSION
BUT LIKE
FIRE CAN BE CONTROLLED IN A FURNACE TO GENERATE HEAT AND POWER
ALSO
A FISSION CHAIN REACTION CAN BE CONTROLLED IN A REACTOR TO GENERATE HEAT AND POWER

FIGURE 2. (READ EACH COLUMN FROM TOP TO BOTTOM) of radioisotopes were produced in cyclotrons or "atom smashers." These radioisotopes, furthermore, were expensive. The cost in 1942 of producing Tritium (H 3) in some cyclotrons, for example, was approximately $10,000 per millicurie. Tritium is produced in AEC reactors for less than one cent per millicurie. Large quantities of a wide variety of other radioisotopes are produced in AEC reactors at reasonable cost.

In 1946 the Manhattan Engineer District, predecessor of the Atomic Energy Commission, initiated a program of producing and distributing radioisotopes for medical, industrial, agricultural, and research purposes. As of July 31, 1956, the Oak Ridge National Laboratory alone had made 84,933 shipments of radioisotopes. (See Figure 3, Increase in Radioisotope Shipments, p. 138.) Shipments have been made to scientists, institutions, teachers, and physicians in 51 other countries. Figure 4 (See Types of Radioisotope Users on p. 138.) shows the great number and variety of radioisotope users in the United States. The AEC's radioisotope distribution program has played an important role in the rapid growth and utilization of radioisotopes, the most noteworthy peacetime application of atomic energy to date.

It has been estimated that the use of radioisotopes saved American industry as much as $180 million in 1954, as follows:

Estimated Annual Savings in Millions of Dollars

Radioisotope Thickness Gauges	$100
Radiographic Testing	18
Consulting Laboratory Services	40
Catalytic Cracking of Petroleum	10
Radioactive Piston Rings	5
Pipeline Oil Flow	2
Miscellaneous	5
Total	$180

RADIOISOTOPES IN MEDICAL RESEARCH, DIAGNOSIS, AND THERAPY

More than 1400 medical institutions and research groups in the United States are currently employing radioisotopes in the search for information that may elucidate the origin and development of malignancies and other diseases and suggest possible means of combating them. The human body is a complex and exceedingly active chemical laboratory whose proper functioning is dependent upon a series of internal checks and balances and adaptation to trauma and injurious agents. The paucity of information regarding metabolic and other functions of the human mechanism has seriously handicapped research

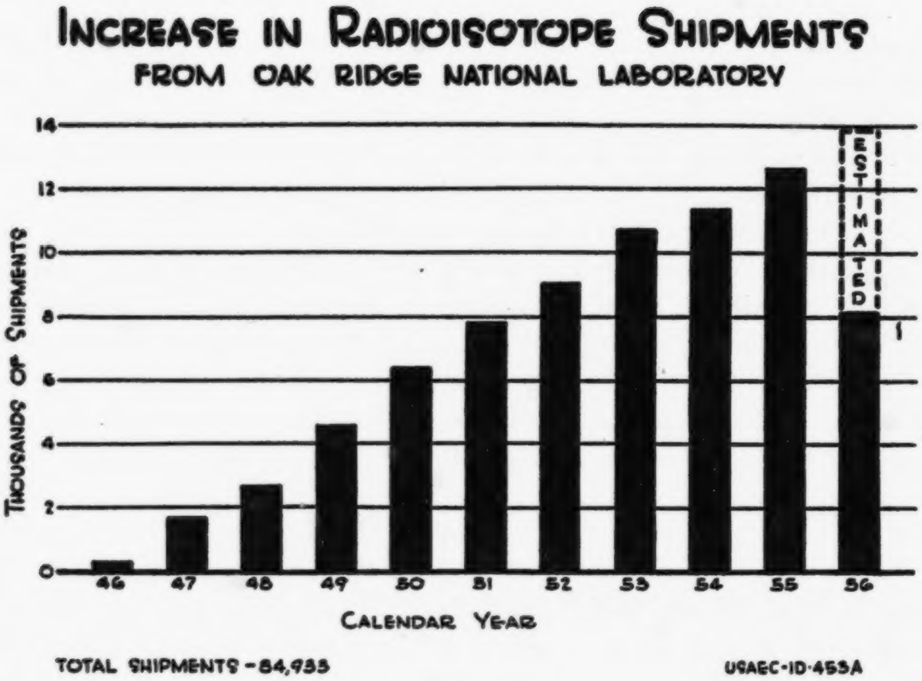


FIGURE 3

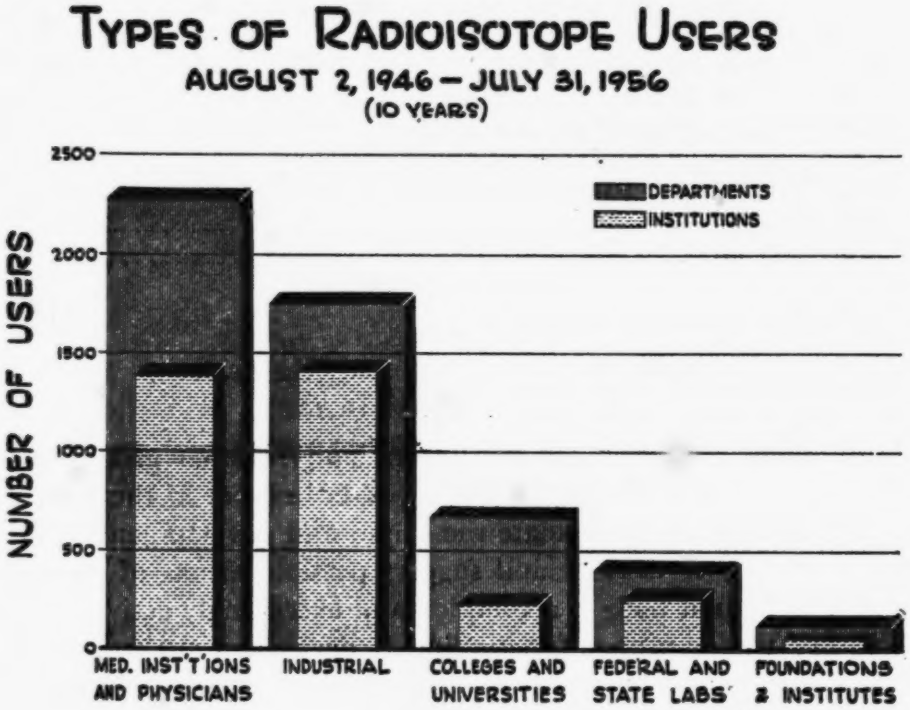


FIGURE 4

teams attempting to combat disease by chemotherapy and other direct means.

Possibly the greatest value of radioisotopes lies in their utility as research agents. It is possible, for example, to "label" or "tag" a particular hormone with a radioisotope such as Iodine 131 and follow its fate in the body, utilizing a sensitive instrument to detect the radiation emitted by the radioactive material. Radioisotopes may be detected even though diluted by a factor of several billion. Either the hormone or the substance upon which it acts may be labeled. The formation, utilization, and storage of fats, carbohydrates, proteins, and mineral constituents of the body have been studied with fruitful results. The pituitary-thyroid relationship, the role of sodium in hypertension, potassium in muscular dystrophy, calcium in osteoarthritis and high blood pressure, iron metabolism, and action of drugs, are examples of other studies with radioisotopes which have resulted in valuable data.

Our understanding of the role of cholesterol, important in both malignancies and arteriosclerosis, has been greatly enhanced through research techniques employing radioisotopes. Numerous investigations using radioisotopes as tracers have been devoted to organic and inorganic compounds known or suspected of producing cancer. The search for anti-cancer drugs is proceeding on several levels, including both direct attempts to achieve therapeutic results and indirect efforts to learn more about the metabolic characteristics of the various types of malignancies.

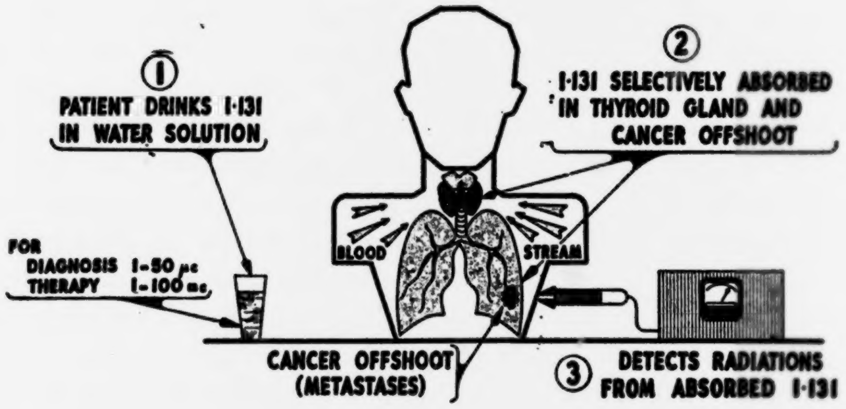
It has been determined that leukemic tissues tend to concentrate phosphorus and that nucleic acids (essential to production of protoplasm) contain phosphorus. The potassium ion relationship in muscular dystrophy is receiving close attention. Nephrosis, with its mortality rate of over 50 percent is being studied with a wide variety of radioisotopes. Epidemiological studies directed at relating subjects, infectious agents, and transmitting agents or vectors, have resulted in a wealth of information regarding the spread of disease—data that in some instances may have been impossible to obtain by other methods.

Basic research in many other fields has given us helpful information. Extremely sensitive measurements and techniques made possible by radioisotopes have proved that the electrical pulses associated with the nervous system are caused by the movement of sodium and potassium into and out of the nerve cell. The end effect of this and related studies may well point the way to ultimate victory over mental disease.

It is possible that more basic, reliable, physiological data have been

RADIOACTIVE IODINE — I·131

FOR DIAGNOSING AND TREATING THYROID GLAND DISORDERS

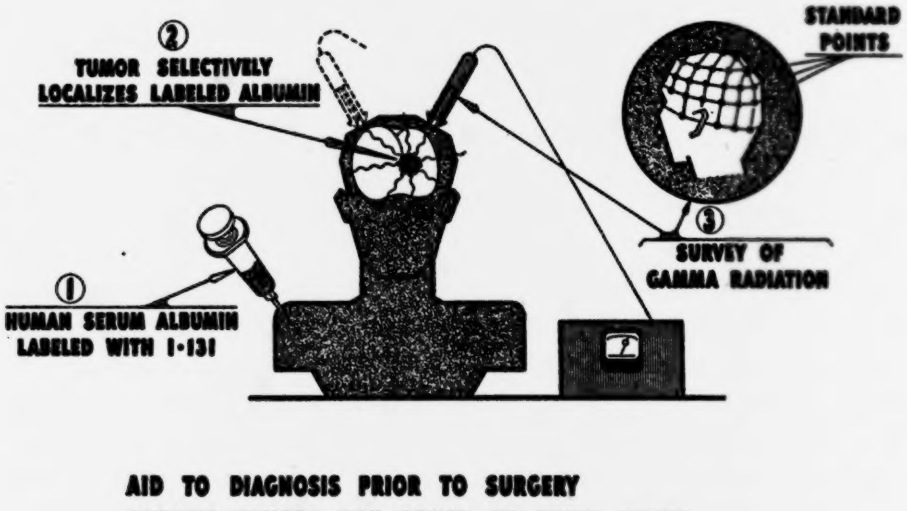

①
PATIENT DRINKS I·131 IN WATER SOLUTION
②
I·131 SELECTIVELY ABSORBED IN THYROID GLAND AND CANCER OFFSHOOT
FOR
DIAGNOSIS 1–50 μc
THERAPY 1–100 mc
BLOOD
STREAM
CANCER OFFSHOOT (METASTASES)
③
DETECTS RADIATIONS FROM ABSORBED I·131

MEDICAL ACTION:

1 - DIAGNOSIS AND TREATMENT OF HYPERTHYROIDISM
2 - LOCATION OF THYROID CANCER OFFSHOOTS (METASTASES)
3 - TREATMENT OF THYROID CANCER AND METASTASES

FIGURE 5

LOCATING BRAIN TUMORS
WITH
I·131—TAGGED HUMAN SERUM ALBUMIN


STANDARD POINTS
②
TUMOR SELECTIVELY LOCALIZES LABELED ALBUMIN
③
SURVEY OF GAMMA RADIATION
①
HUMAN SERUM ALBUMIN LABELED WITH I·131

AID TO DIAGNOSIS PRIOR TO SURGERY
LOCATES TUMORS NOT FOUND BY OTHER MEANS
CAN USE MULTIPLE COUNTERS FIXED IN STANDARD POSITIONS

FIGURE 6

obtained in the past decade through radioisotope techniques than were developed and compiled by man in all of the preceding decades and centuries. Undoubtedly some of this work will lead to a breakthrough on many diseases which for all practical purposes must be labeled incurable at this time.

There are immediate benefits from the use of radioisotopes as adjuncts to other methods of diagnosis and therapy. As of the close of 1955 more than 400,000 patients had received Iodine 131 for measurement of thyroid function and diagnosis of thyroid disease or dysfunction. See Figure 5, Radioactive Iodine–1.131, found on p. 140. The radioactive iodine in such instances is administered orally as a practically tasteless liquid. Inasmuch as radioiodine emits penetrating rays, its rate of absorption by the thyroid may be ascertained by placing a sensitive radiation detector on the neck proximate to the gland and noting its response. If the gland is overactive the rate of iodine absorption will be higher than in normal individuals. Thus, the radiation measurement will be greater. The conventional basal metabolism test is not particularly accurate in the diagnosis of thyroid activity (approximately 65 percent accuracy) whereas the accuracy with Iodine 131 ranges from 75 to 90 percent depending upon technique and other factors.

Hyperthyroidism (excessive functional activity of the thyroid gland) responds well to radioiodine therapy. Frequently, striking relief is obtained within the first two or three weeks following administration of the radioiodine. Radioiodine is particularly useful where the patient is a poor surgical risk. In one instance a patient had undergone six operations with recurrence of hyperthyroidism each time. The thyroid returned to normal after radioiodine therapy and there were no recurrences during the following five years that the patient's condition was followed. As a patient's thyroid assumes normal functioning, the enlarged gland diminshes in size, strength is regained, high pulse pressure is reduced, tremor and marked nervousness disappear, tachycardia (fast heart beat) is reduced.

Radioactive iodine is useful in certain cardiac conditions. It has been known for some time that surgical removal of the thyroid gland gives relief in certain heart conditions such as angina pectoris and congestive heart disease. Although one out of two patients benefit from such surgery the mortality rate is discouraging. Antithyroid drugs offer some relief, but their usefulness is seriously limited by several factors. Iodine 131 therapy, however, offers excellent results in 50 percent of angina cases and good results in another 15 or 20 percent. Some patients who have been incapacitated for a number of years are now gainfully employed after Iodine 131 therapy. Increased capacity to work without pain was observed in a majority of cases. Iodine 131, through its selective destruction of a portion of the thyroid tissues, reduces the metabolic rate. This lowers the body's demands for oxygen and decreases the work which the heart must perform to a point where the patient can live comfortably.

Good to excellent results have been obtained in congestive heart disease through this same mechanism. This is not a cure in the strict sense, but does permit metabolism to be adjusted at a level where relief from pain is obtained with a minimum of discomfort from the lowered metabolism. The risks and complications of surgery are also avoided.

Good results, mostly of a palliative nature, have been obtained in a small number of cases of thyroid cancer. Only a small percent of thyroid cancers, however, are amenable to such therapy. Radioiodine has been used to advantage in a number of other diseases and conditions. One extensive use is precise determination of blood volume in preoperative cases and in wounded or injured persons who have suffered a significant but undetermined loss of blood.

Phosphorus 32 is considered by many authorities to be the treatment of choice in polycythemia vera, a disease characterized by an excess of red blood cells. Radioactive phosphorus is easy to administer, dosage can be controlled readily, and radiation sickness which accompanies X-ray treatment for this same purpose is avoided. Remission of six months to two years has been obtained with significant relief of the severe headaches, fatigue, dizziness, splenic pain, and other symptoms typical of this condition. Fair results have been achieved in some forms of chronic leukemia. Although symptomatic relief has been obtained in chronic leukemia such therapy with P 32 does not prolong life appreciably over other methods of treatment.

In some instances it is desired to treat a tumor by placing the radioactive material directly into the tumor. Cobalt 60 and Gold 198 as needles, wires, beads, or other sources of radiation for this purpose are rapidly replacing the more costly and less satisfactory radium needles. Teletherapy units, incorporating a sealed source of radioisotopes such as Cobalt 60 or Cesium 137, permit treatment of deep-seated malignant conditions with less destruction of skin and underlying tissues. Teletherapy units are more compact than X-ray machines and are more suitable for moving field therapy. The net cost of Cobalt 60 treatment may be approximately one-half that of treatment with an equivalent X-ray machine.

Strontium 90 is used as a beta-ray source in treating diseases of the eye. Radioactive gold colloid is useful in treating carcinoma of the uterine cervix and carcinoma of the prostate. Metastatic tumors resulting in accumulation of fluid in the chest and abdominal cavities may be treated with colloidal radioactive gold or chromic phosphate. Usually good results are obtained in mitigating complications and alleviating to some extent the patient's discomfort and suffering.

Radioactive sodium is useful in the diagnosis of circulatory disorders. Often it is possible to locate the precise point of impairment or constriction of a blood vessel and indicate whether incision or amputation is necessary and at what point.

When injected into a patient, human serum albumin labeled with Iodine 131 concentrates in brain tumor tissues. A sensitive radiation detector placed over the skull at different points measures the radioactivity emitted from the tumor, thereby facilitating precise location, an important aid to surgery or therapeutic radiation. (See Figure 6, Locating Brain Tumors, on p. 140.) Radioisotopes such as Phosphorus 32 have proved useful in distinguishing between benign and malignant growths.

As a research tool radioisotopes represent another milestone in man's progress as important as the microscope. As diagnostic and therapeutic agencies, radioisotopes are valuable adjuncts to other modalities available to the physician in treating the maladies of man.

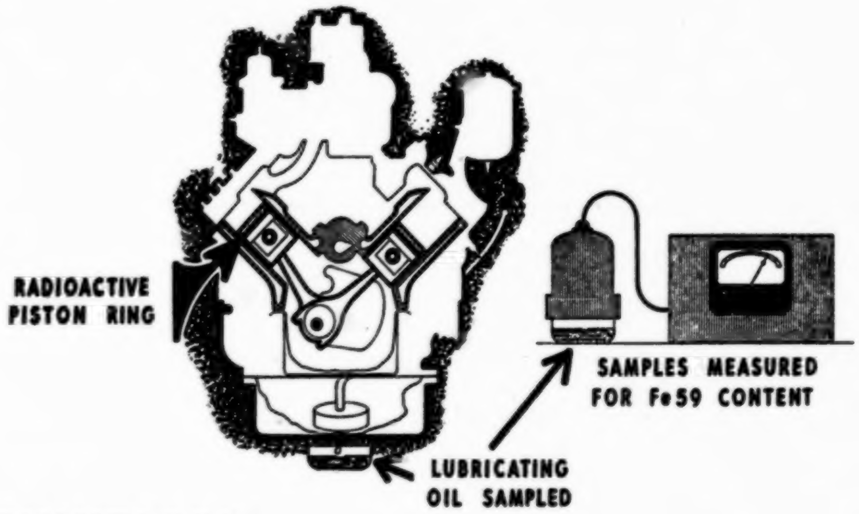
INDUSTRIAL USES OF RADIOISOTOPES

More than 50 percent of the institutions using radioisotopes in the United States are industrial firms. Radioisotopes have made possible better products at less cost in many industrial operations.

Friction and lubrication studies serve as an excellent illustration of the versatility and sensitivity of radioisotope techniques. Piston rings, for example, (See Figure 7 on p. 144.) are inserted into a nuclear reactor and subjected to neutron bombardment which renders them radioactive. The ring is fitted to the piston using appropriate measures to protect personnel from the radiation. Following assembly of the motor and addition of lubricating oil, the engine is started. Radioactive iron worn from the piston rings can be detected in the oil within 15 minutes and serves as a direct indicium of the amount of wear of the piston ring and efficiency of the lubricating oil. In one study conventional methods of measuring engine wear would have cost $1 million and taken 60 man-years. Radioisotope techniques revealed the required information at a cost of $35,000 and required only four man-years.

RADIOACTIVE IRON — Fe 59

FOR FRICTION AND LUBRICATION STUDIES


RADIOACTIVE PISTON RING
SAMPLES MEASURED FOR Fe59 CONTENT
LUBRICATING OIL SAMPLED

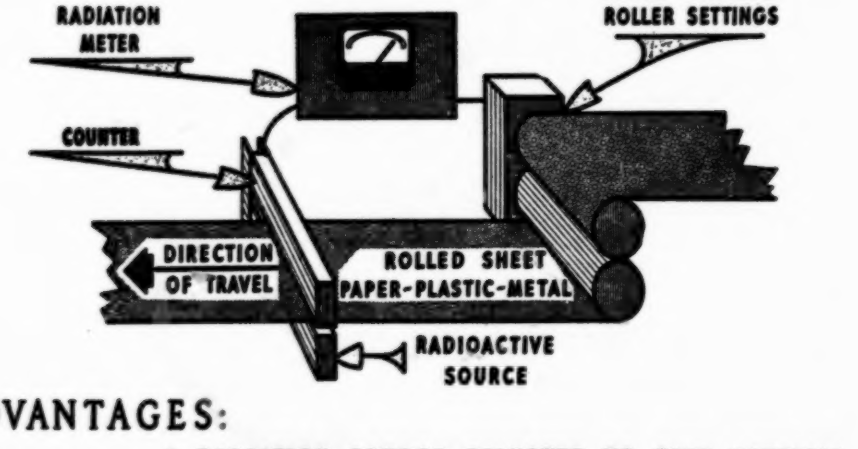
ADVANTAGES:

1 - TRANSFER OF METAL MEASURED TO $\frac{1}{100{,}000}$ OUNCE
2 - OIL SAMPLED DURING OPERATION OF MOTOR
3 - RAPID — SIMPLE — ECONOMICAL

FIGURE 7

RADIOACTIVE SOURCE

FOR GAGING THICKNESS


RADIATION METER
RADIATION METER CONTROLS ROLLER SETTINGS
COUNTER
DIRECTION OF TRAVEL
ROLLED SHEET PAPER-PLASTIC-METAL
RADIOACTIVE SOURCE

ADVANTAGES:

1 - RADIATION SOURCE SELECTED TO SUIT MATERIAL
2 - NO CONTACT - NO TEARING - NO MARKING MATERIAL
3 - RAPID AND RELIABLE

FIGURE 8

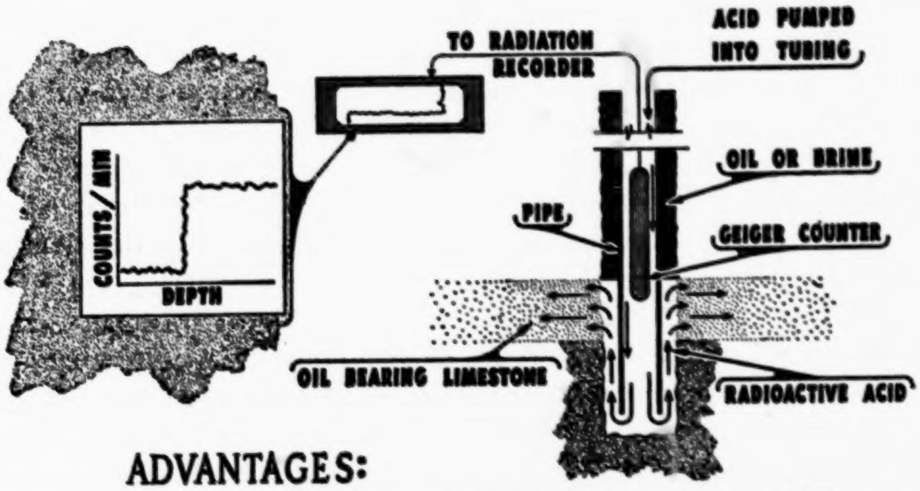
A great number of radiation gauges are currently in use in this country measuring all types of materials including paper, aluminum, iron, copper, cigarettes, rubber, plastics, abrasives, tape, and a variety of other materials and products. Although a number of radioisotopes are used in these gauges Strontium 90 is the most commonly used beta-ray emitter. The transmission type thickness gauge consists of a radioactive source and a radiation detector connected to an amplifier and recording device. The material being measured is passed between the radiation source and detector. The radiation reaching the detector varies according to the thickness or density of the material. Variations in thickness are quickly determined and machine adjustments made without stopping the operation, Reflection-type thickness gauges are employed in measuring and controlling the deposition of coatings such as adhesive on tape, or abrasives on sandpaper. See Figure 8, Radioactive Source on p. 144, illustrating a typical transmission type thickness gauge.

Radiographic testing is another important use of radioisotopes such as Cobalt 60, Iridium 192, and Cesium 137. Radium and X rays have been used for making X-ray pictures of welds, oil pipes, steam lines, boilers, engine blocks, firearms, and other structures for a number of years. Reactor produced radioisotopes, however, are considerably cheaper and more versatile in some cases. Internal cracks and flaws may be detected by such pictures thereby contributing to greater safety and minimizing costly failure during operation. Radioisotope radiographic equipment may cost $2000 as opposed to $50,000 for equivalent X-ray equipment. It is interesting to observe the relative size of a Cobalt 60 capsule (large as a thimble) as opposed to the bulky and complex X-ray equipment.

Oil well acidizing is another example of effective and economical use of radioisotopes. In order to increase the yield of oil-bearing strata it is often necessary to render the strata more porous through the use of acid. This ordinarily entails removal of the tubing through which the acid is introduced (several thousand feet of pipe as a rule). As noted in Figure 9, Radioactive Isotopes, found on p. 146, a radiation detector is suspended in the pipe at the proposed depth for acid treatment. A small amount of radioactivity is added to the acid. If the radioactive acid fills the well to the height of the radiation counter, the response of the instrument will be maximal. If the radiation intensity measured by the instrument is weak it may be necessary to add more acid.

Oil well logging is another useful application of radioisotopes. A sealed source emitting neutrons (such as a polonium-beryllium source)

RADIOACTIVE ISOTOPES
FOR CONTROL OF OIL WELL ACIDIZING

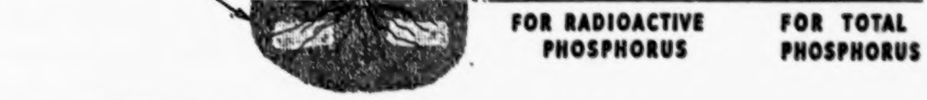

TO RADIATION RECORDER
ACID PUMPED INTO TUBING
COUNTS/MIN
DEPTH
OIL OR BRINE
PIPE
GEIGER COUNTER
OIL BEARING LIMESTONE
RADIOACTIVE ACID

ADVANTAGES:

1 - PERMITS CONTROLLING SITE OF ACID ACTION
2 - INCREASES EFFICIENCY OF OIL PRODUCTION
3 - SAVES TIME AND MONEY
4 - LESS HAZARDOUS THAN REMOVING PIPE

FIGURE 9

RADIOACTIVE PHOSPHORUS – P32
FOR STUDY OF PHOSPHATE FERTILIZER UPTAKE


① P32 INCORPORATED IN FERTILIZER
② LABELED FERTILIZER ADDED TO SOIL
③ PLANT AND SOIL MEASURED
FOR RADIOACTIVE PHOSPHORUS
FOR TOTAL PHOSPHORUS

SHOWS:

1- FIXATION OF PHOSPHORUS BY SOIL
2- PHOSPHORUS UPTAKE BY PLANT
3- PROPER TYPE AND PLACEMENT OF FERTILIZER
4- EFFICIENCY OF FERTILIZER

FIGURE 10

and a radiation detector are placed at the bottom of a bore hole. Response of the detector as the source is slowly drawn up gives a good idea of the porosity and water or hydrocarbon content of the surrounding soil. Radioactive iodine has also been employed to ascertain the integrity of the cement job at the lower end of the oil well casing.

Static electricity has proved to be a serious problem in many industrial operations. It presents a potential fire hazard in many instances and gives rise to technical difficulties in paper mills, printing plants, and other similar industrial or commercial operations. The use of radioisotopes such as Polonium 210 and Strontium 90 neutralizes static electricity permitting machine jogging and increasing the number of sheets handled per man-hour. It is reported that some firms have effected a savings of $200 to $300 per day as the result of using static eliminators.

Static electricity also interferes with fine grinding operations. Neutralization of such charges through the ionizing effect of radioisotopes permits finer grinding, particularly important in such activities as the cement industry. Static eliminators are also used widely as an aid in cleaning photographic films, phonograph records, and other surfaces where dust is particularly troublesome.

Small amounts of radioisotopes are added to electronic tubes to ionize the enclosed gases and facilitate electrical discharge. Addition of beta-ray emitters to fluorescent lamps results in faster starting time with lower voltages.

Electron printing is an interesting application of radioisotopes. A picture may be painted or printed with radioactive paint or ink. The picture may be reproduced by placing it in contact with photographic paper and then developing the paper.

The textile industry is using radioisotopes in many ways, one of which is to control dye migration and prevent soiling of fabrics. A radioisotope is added to the predominant dye of the textile pattern. A radiation counter is suspended in the dye box which has the most sensitive color. Detection of radiation in the dye box with the sensitive color indicates that the primary color is mixing with the sensitive color.

Valuable data have been compiled regarding the relative efficiency of specific detergents and other cleaning agents. Various substances such as fats and clays are labeled with radioisotopes such as Carbon 14 and are placed on swatches of cotton cloth. The cloths are washed in various types of machines, with different detergents. Measurement of the radioactivity on the cloth is an index of the amount of dirt remaining and indicates the effectiveness of the detergent, washing machine, or washing technique.

Although materials may be damaged by the deleterious effects of ionizing radiation, desirable modification of structure or characteristics may also result. The melting point of certain plastics, for example, may be raised from 70° to 200° centigrade through radiation. Such improved plastics retain their desirable characteristics, flexibility at average temperatures, and yet are stable and unharmed when subjected to higher temperatures.

Cold sterilization of heat sensitive drugs is another promising use of radioisotopes. Sterilization of penicillin, for example, is expensive and relatively difficult. Sterilizing sutures and other heat sensitive items is also a difficult problem. Radiation from radioisotopes can be used with effect in these instances. Irradiated vaccines are more potent and effective, generally, than when prepared by other means.

Pasteurization of foods by ionizing radiation, a possibility conceived as far back as 1930, is undergoing intensive study. Sprouting and rotting of potatoes, for example, can be delayed for many months. Certain technical problems must be solved before this particular application of radioisotopes can be placed in widespread use. Off-flavor and odors must be eliminated; absence of toxic or possible carcinogenic effects must be established. Modification of nutritive values, vitamins, enzymes must be determined. Rats fed on irradiated foods have shown retarded growth in some cases. More rapid growth has been noted in other instances.

The importance of this field of use is apparent when we consider that food processing is a $60 billion business in this country. Consider also that 50 percent of some fresh products spoil before they reach the ultimate consumer. The shelf life of certain foods can be extended by a factor of 10 or more if pasteurized by radiation. Consider also the numerous diseases transmitted to man through food. Trichinosis, resulting from undercooked infected pork, affects 16 percent of our population to some degree, 2 percent of our swine being infected with the parasite. The parasitic worm may invade the heart muscle, lungs, and brain. Chronic muscle soreness and mild nausea resulting from trichina is often attributed to other causes. Irradiation of pork and pork products could virtually eliminate trichinosis within a few years. Beef tapeworm, affecting an even greater number of persons, can also be destroyed by ionizing radiation.

Many materials luminesce or emit light rays when struck by atomic particles. Radioisotopes such as Strontium 90 are used in manufacturing self-luminous markers which will continue to glow for a number of years independent of any other source of energy. Such radioisotope-activated-markers provide a constant level of light and are particularly useful to mark exits to public buildings, stairways, tunnels, mines, instrument dials, etc.

Several atomic batteries have been developed that provide a constant current of essentially any voltage from a fraction of a volt to several thousand volts. These batteries have several specialized applications in a number of fields.

Radioisotopes are utilized in determining soil density and water content accurately and rapidly. Knowledge of subsoil conditions is exceedingly important in constructing highways, airport runways, and dams. A determination can usually be made in three to five minutes whereas conventional measurements may require 30 minutes or more.

Other industrial applications of radioisotopes include the tracing of underground sewers, locating markers under snow and soil, detecting levels of hazardous liquids without exposing personnel to danger, studying the wear of tires and other automotive parts, measurement of films and deposits on surfaces, detecting interfaces of oil in pipeline flows, detecting leakage of oil through seals and loss of coolants in automotive engines and other closed systems.

There is little question that radioisotopes are indispensable tools to progressive-minded industry interested in improved products and/or lower production costs. Frequently both objectives are realized through the use of radioisotopes.

RADIOISOTOPES AND AGRICULTURE

Radioactive carbon and other radioisotopes have been used to advantage in solving some of the complex processes of photosynthesis whereby green plants convert solar energy into chemical energy. Scientists have acquired a better understanding of the respective roles of radiant energy from the sun, carbon dioxide, water, and chlorophyll. Through the use of Carbon 14 it has been possible to follow various chemical reactions that take place during photosynthesis. As a result of this valuable data man is several steps nearer to possible duplication of nature's vital, secret process. At least six of the probable 12 steps in photosynthesis have been duplicated by man. The Japanese, as a result of pertinent studies with radioisotopes, have controlled the production of algae for use as cattle fodder.

More than $1 billion annually is spent on fertilizers by farmers in the United States. It is understandable, therefore, that the widest use of radioisotopes in agriculture has involved fertilizer uptake studies. Farmers in the United States and other countries are already benefiting from information gained as a result of these studies. A typical study is illustrated in Figure 10, Radioactive Phosphorus, p. 146, in which radioactive phosphorus is added to fertilizer which is then applied to the soil. As the "labeled" fertilizer component (phosphorus in this instance) moves into the plant the rate of uptake and ultimate placement in the plant can be determined by a Geiger counter or other instrument measuring the radiation therefrom. It is possible not only to determine the merits of a particular fertilizer, but also to make reliable evaluation of different methods of fertilizer application.

Radioisotope techniques have proved that plants absorb food through the leaves, fruit, and trunk, as well as through the roots. Application of nutrients to the foliage may result in 95 percent of the nutrient being absorbed by the leaves. Uptake from the soil may range from 5 to 15 percent. Thus, a leaf is very efficient in this regard. Root feeding, however, is essential in some instances (e.g. if strawberries are to utilize calcium profitably). Radioisotope experiments have proved that spraying dormant trees with fertilizers results in better fruit the following year.

Until investigations with radioisotopes proved otherwise it was "well established" that alfalfa was an inadequate source of phosphorus for lambs. Labeling alfalfa with Phosphorus 32 and following its fate when fed to lambs proved that approximately 90 percent of the phosphorus in alfalfa is utilized.

Formation of milk in cows has been studied with Carbon 14 and other radioisotopes. The respective roles of iodine, sulfur, cobalt, vitamin B_{12}, copper, and other materials in formation of milk are undergoing intensive study. Carbon 14 is particularly useful in these studies inasmuch as essentially all feed nutrients contain carbon in varying amounts.

The effect of viruses, fungi, and other injurious agents on plants is receiving increased attention. The American farmer spends over $80 million annually for insecticides and fungicides. Many plant conditions previously deemed the result of malnutrition are now considered to result from virus attacks. Basic research using radioisotopes as tracers is shedding valuable light on the etiology and pathogenesis of such conditions and plant diseases. The importance of developing hardier strains of crops, of learning more about the diseases that affect them, of producing more effective fungicides, is self-evident when we consider that plant diseases cost the American farmer more than

$3 billion annually. In some instances 50 to 75 percent of wheat, oats, and potatoes have been destroyed in certain areas. From 20 to 40 percent of the sweet potato crop is lost each year as the result of some 50 different fungi diseases.

"Radiation genetics" is a rapidly growing field of applied research which has already resulted in significant contributions to agriculture. Radiation has been employed to induce desirable mutations in various plants, to render them hardier and more resistant to viruses and other injurious agents. Rust-resistant oats have been developed through radiation induced mutations. Corn has also been produced which is highly resistant to certain viruses and fungi.

Irradiating seeds not only has created new varieties of plants that are disease resistant, but has also resulted in other desirable characteristics. Peanuts have been produced with 30 percent higher yield per acre which can be more readily harvested by mechanical means. Other plants have been developed with greater uniformity in size, accelerated maturation. Plant geneticists have produced barley with a higher yield of grain and straw. Increased yield has also been achieved in varieties of wheat which also have a high degree of resistance to stem rust.

Insects cause extensive damage to growing crops and during storage. Losses of stored grains alone may run as high as $150 million a year in some instances. Grain losses may be 40-50 percent as a result of insect infestation. Irradiating such grains with appropriate radiation doses will minimize or eliminate the reproduction of insects in such foods.

The screwworm, which costs the livestock industry more than $25 million annually, can be controlled through radiation. In one study large numbers of male flies were sterilized with radiation and released. The female mates only once, and if this occurs with a sterile male the eggs will not hatch. The screwworm was ultimately eliminated on the island of Curaçao by this technique. The pink bollworm in cotton seed may also be destroyed by radiation from radioisotopes.

Radioisotopes are being used to find better growth regulators and herbicides. Labeling a herbicide with radioactive Carbon 14 or other radioisotopes permits the scientist to follow its absorption by various plants. This facilitates an evaluation of its efficiency and possible effects on persons or animals who may consume the plant. Considering crop losses and increased costs of tillage, weeds cost the American farmer $5 billion annually.

The spread of diseases common to honey bees has been studied with effect. Radioactive phosphorus is added to sugar syrup and a

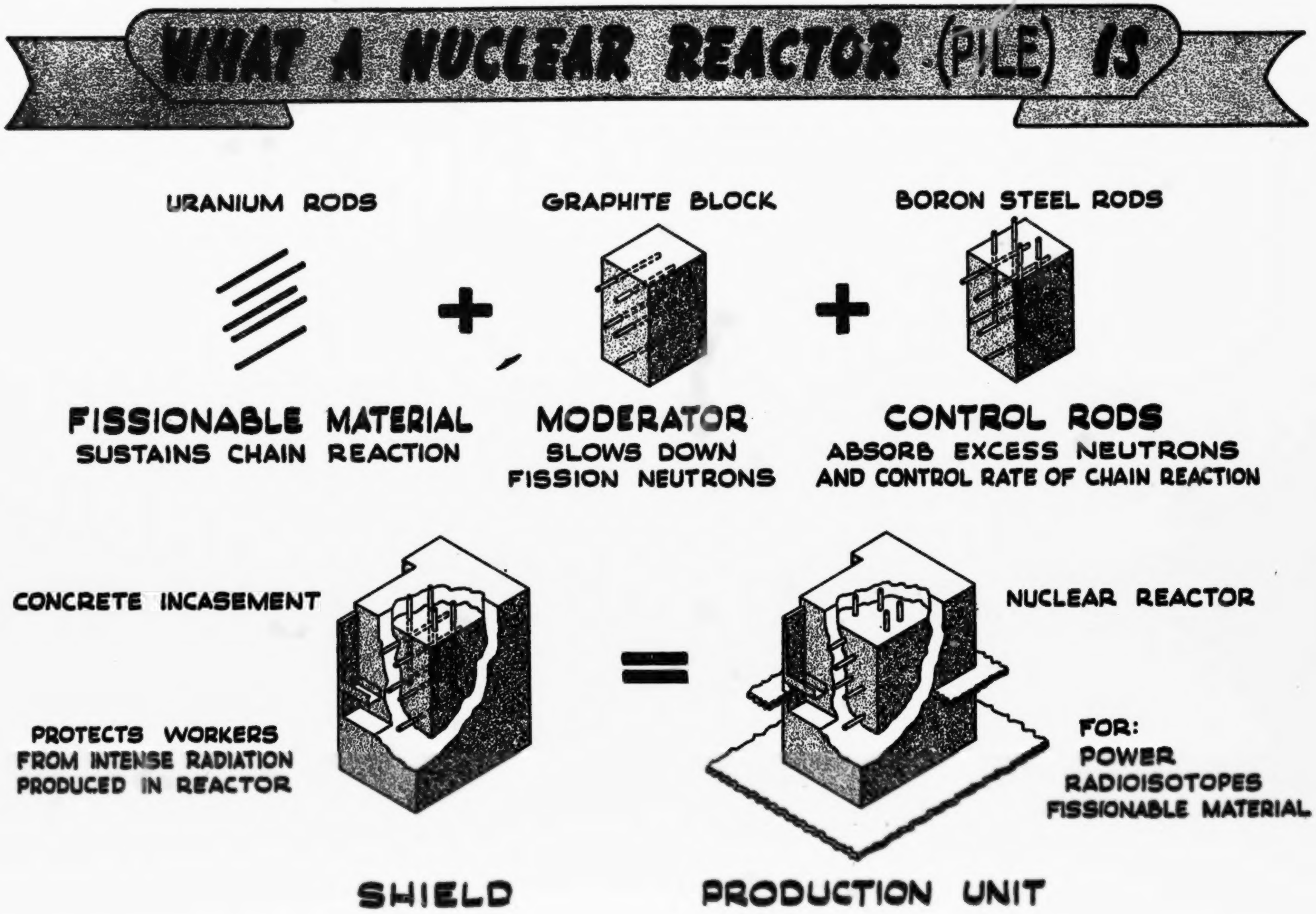

WHAT A NUCLEAR REACTOR (PILE) IS
URANIUM RODS
GRAPHITE BLOCK
BORON STEEL RODS
+
+
FISSIONABLE MATERIAL
SUSTAINS CHAIN REACTION
MODERATOR
SLOWS DOWN
FISSION NEUTRONS
CONTROL RODS
ABSORB EXCESS NEUTRONS
AND CONTROL RATE OF CHAIN REACTION
CONCRETE INCASEMENT
PROTECTS WORKERS
FROM INTENSE RADIATION
PRODUCED IN REACTOR
=
NUCLEAR REACTOR
FOR:
POWER
RADIOISOTOPES
FISSIONABLE MATERIAL
SHIELD
PRODUCTION UNIT

FIGURE 11

colony of bees is permitted to feed thereon. The bees are thus "tagged" slightly with radioactivity. "Drifters" that find their way to other colonies may be detected by a Geiger counter or other radiation detection instrument. This drifting may be correlated with the spread of various diseases such as "foulbrood."

Diseases and abnormalities of farm animals have also been studied with radioisotopes. Bloat in sheep and ketosis in dairy cattle are examples of diseases in which radioisotopes have proved to be useful research tools. Radioisotopes are used also to produce desirable mutations in poultry and other animals. Beta-ray applicators incorporating radioactive strontium are used directly in therapy of eye and skin infections in farm animals. Iodine 131 is playing an important role in research aimed at developing breeds of cattle in the United States that will be excellent milk producers and have a high heat tolerance equivalent to Indian breeds.

Extensive research, fundamental and applied, is being carried out with radioisotopes in agricultural areas. Although the farmer has little direct contact with atomic energy he is receiving the benefits of this new force through improved fertilizers, insecticides, fungicides, herbicides, improved varieties and strains of plants with higher yield and greater disease resistance.

NUCLEAR REACTORS

There are many types of nuclear reactors which may be categorized according to physical characteristics or intended use. As illustrated in Figure 11, which appears on the opposite page, a nuclear reactor is comprised of a fissionable material such as Uranium 235, a moderator to decrease the speed of neutrons emitted by the fissionable material, a coolant, control rods to absorb excess neutrons and control the fissioning process, all surrounded by concrete or other shielding to protect personnel from the harmful effects of the intense radiation.

The fuel may be solid or in solution; the reactor may be cooled by air, gases, heavy water, ordinary water, sodium, mercury. The moderator (which serves to slow the neutrons, thereby increasing the probability of such neutrons being captured by a uranium nucleus) may be graphite, beryllium, graphite-H_2O, or heavy water. Control rods may be made of cadmium, boron, or other neutron-absorbing materials. Thus, upon the basis of physical characteristics we have a wide variety of reactor types—the water boiler reactor, graphite, sodium graphite reactor, liquid metal fueled type, swimming pool, organic moderated reactor, fast breeder, and many others.

Categorization according to primary use is much simpler although a particular reactor can be adaptable to several uses. These uses may be classified generally as (a) research, (b) medical, (c) testing, (d) production, and (e) power.

RESEARCH REACTORS

Research reactors are used primarily as sources of neutrons and gamma rays. The first university research reactor to be placed in operation in the United States is located at North Carolina State College. A second reactor was completed and placed in operation in 1956 by Pennsylvania State University. The Atomic Energy Commission, of course, has operated a number of research reactors during the past several years and invaluable data have been obtained in the AEC's research program.

In addition to those in the United States a number of other countries are constructing or planning research reactors, including the United Kingdom, Soviet Union, Canada, France, Norway, the Netherlands, Sweden, and Switzerland. India has two reactors planned for completion in 1956 and 1957. The United States is making 21 tons of heavy water available to India. This will be used in a research reactor which Canada will furnish.

A great deal of fundamental and applied research is made possible through research reactors. Several standardized types and sizes, at reasonable cost, are now available to universities and research institutions. The Atomic Energy Commission provides assistance to such research reactor projects.

One important use of a research reactor is "Activation Analysis" which permits detection of trace elements with a high degree of sensitiveness and accuracy. A weighed amount of material to be analyzed is irradiated with slow neutrons together with a sample or monitor which contains a known weight of the element to be measured. The element of interest is separated chemically. Radioactivity of the sample and monitor is then measured with a suitable radiation detection instrument and compared. Comparison of the radioactivity permits the analyst to determine the amount of trace element in the sample of interest. This procedure is particularly useful in ascertaining amounts of trace elements in various products such as paints, refined chemicals, metals, plastics, etc. As a matter of fact discrepancies between polarographic and spectrochemical methods have been reconciled in a number of instances through activation analysis.

Many radioisotopes of extremely short half-life (seconds or minutes) can be produced in such reactors and experiments run on the spot or in nearby laboratories—experiments that would be impractical if such radioisotopes were obtained from distant reactors. Radioactive potassium, for example, is very useful in brain metabolism studies but short half-life has limited its use. Such reactors are also useful in studying the effects of ionizing radiation on various materials, inducing mutations in seeds and plants. These reactors also serve as training aids in meeting the need for more trained nuclear engineers and physicists.

MEDICAL RESEARCH AND THERAPY REACTORS

Important medical research has been accomplished at the AEC's Brookhaven National Laboratory, pointing to the desirability of additional reactors designed expressly for medical purposes. In comparison with the use of radioisotopes, however, our experience with reactors for diagnostic or therapeutic purposes is limited.

Neutron capture therapy is one example of a potentially useful medical application of reactors. Glioblastoma Multiforme is a type of brain tumor for which there is no satisfactory treatment. If Boron 10 is injected into the blood stream it will be taken up by the tumor tissue sooner than by the normal brain. If the tumor and adjacent tissues are subjected to neutron bombardment the Boron 10 captures the slow neutrons and becomes radioactive. Alpha particles from the radioactive boron (which disintegrates into lithium and helium) destroy the tumor cells without extensive damage to normal tissues. Results are encouraging clinically. Rather than administering Boron 10 as borax much greater concentration in the tumor may be possible if administered in the form of certain dyes.

Medical reactors will prove useful where a copious supply of neutrons or intense gamma field is required. The reactor will offer a wide variety of radiations suitable for specific therapeutic requirements and permitting a wide range of depth of penetration. Short-lived medical radioisotopes can be produced and administered to a patient with minimum loss of radioactivity. The precise role that medical reactors will play in man's conquest of disease remains to be seen.

TESTING REACTORS

Irradiation of various materials at high fluxes in testing reactors has given us a wealth of information about such materials and verified or disproved data obtained by other means. There is a great need for more knowledge about radiation damage and radiation effects generally. We are particularly interested in materials that may serve as reactor components. Irradiated nickel is harder with increased grain size. The impact strength of certain steels may be decreased substantially whereas other steels may become stronger as a result of radiation.

Through radiation it is possible to study and change the properties of various materials—increasing or decreasing impact strength, electrical resistivity, hardness, grain size, magnetic qualities, and thermal conductivity. As knowledge is accumulated the world may look forward to a wider variety of improved metals and other materials specially adapted for specialized jobs.

PRODUCTION REACTORS

A production reactor is designed primarily for production of fissionable material such as plutonium. Thus, the ability to convert nonfissionable uranium into fissionable plutonium is of prime importance. Large quantities of fission products are also produced and such reactors may be utilized for production of radioisotopes.

POWER REACTORS

The technical feasibility of "atomic power" has been evident for several years. The enormous economic potential of atomic power is patent when we consider that the energy in a cubic inch (approximately one pound) of Uranium 235, if completely fissioned, would be equivalent to 2.6 million pounds of coal or 240,000 gallons of fuel oil. (See Figure 12 in pictorial insert following p. 134.) A few hundred tons of uranium, *fully utilized,* could supply the world's power needs for one year. Energywise the world's supply of uranium exceeds that of coal by 25 times and would meet the world's power needs for several centuries.

For power purposes a reactor is merely a heat source. This heat energy must be extracted to drive a turbine, actuate the screw of a ship, propellers of an airplane, wheels of a locomotive, or electrical generator to produce electricity for a multitude of purposes. Although many technological and economic problems must be solved before atomic power can compete economically it has already propelled submarines, and experimentally lighted the town of Arco, Idaho.

The cost of electricity in most sections of the United States is generally in the region of 7 mills (7/10 of a cent) per kilowatt-hour. The cost of power is an important factor in initial and continued economic growth of a nation. In 1955 the electrical generating capacity of the United States exceeded 500 billion kilowatt-hours. Needs for electricity in the United States may double in the next 10 years.

Fossil fuels are relatively abundant and cheap in this country. Thus, it will probably be several years before atomic power can compete successfully in the United States. Yet, if the cost of power could be reduced by one mill per kilowatt-hour by 1965 the nation would save $1 billion annually. The rising costs of coal may be moderated to some extent as atomic power is developed. Certain sections of the United States with higher power costs will realize the benefits of atomic power first. Some mining operations, for example, in isolated areas require more and cheaper power. Many arid lands could be irrigated and cultivated profitably if cheaper power were available.

Coal is increasingly expensive in England and many sections of Europe and Asia. The United Kingdom is planning the construction of 16 reactors capable of producing 2000 megawatts of electricity (2 billion watts) and a number of other dual-purpose reactors. Many other countries have long-range plans for power reactors. Generally, atomic power will have little or no disruptive effect on the use of conventional fuels and may stimulate rather than decrease their use. Coal will be used more widely in the manufacture of synthetic liquid fuels and chemicals. Atomic power will supplement, not supplant, fossil fuels.

The future location, or translocation, of industrial plants may be determined in part by the availability of atomic power. Yet, it is not realistic to envisage wholesale movement of industry to other areas solely because of cheaper power. In some industries power costs may represent only a small percent of production costs. Other industries, although heavy users of electricity, must remain close to the source of their raw materials. Pulp and paper mills are examples of this latter group.

Reactor technology is in its early stages. There is a marked need for improved materials and techniques. Fuel reprocessing and waste disposal problems remain to be solved. Costs of plant, equipment, and operation are not certain. It is difficult to forecast with reasonable certainty the useful life of nuclear power plants. Present state of the art does not permit complete burn-up of nuclear fuels. Although atomic power may not compete economically for a number of years, it can supplement and conserve other dwindling sources of fuel.

ATOMIC ENERGY FOR HEATING PURPOSES

In addition to converting atomic energy into electricity such energy may be employed for process or space heating. Ore deposits, for example, could be processed at the mine. Such industries as the primary metals and chemical products, which employ heat extensively, may well profit from the utilization of nuclear heat. Research teams in a number of universities are studying the practicability of nuclear heat for space heating purposes. Nuclear heat offers several advantages—oxygen is not depleted, there are no combustion products, and transportation of fuel is not a serious problem. Nuclear heat utilization may be economically feasible in connection with a multipurpose reactor (for example, production of fissionable materials, radioisotopes, and extraction of heat for space heating purposes).

EFFECT OF ATOMIC ENERGY ON EQUIPMENT MANUFACTURERS AND RELATED INDUSTRIES

Nuclear reactors and radioisotopes have created a demand for various types of instruments and equipment. Prior to 1942 only a few companies manufactured radiation detection instruments. Today, more than 100 companies are engaged in such manufacture, grossing more than $30 million. A number of companies offer consulting services and radiation monitoring services to radioisotope users. An increasing number of firms are engaged in processing and packing radioisotopes commercially. More than 1000 chemical compounds labeled with radioisotopes are now available for research and medical purposes.

Several companies manufacture teletherapy machines for the domestic and foreign market. A wide variety of other equipment is also manufactured—storage containers for radioactive materials, remote handling equipment, etc.

Materials and design requirements for reactor components have had a marked effect on many and varied industries. Reactor pumps for circulating reactor coolants, or liquid fuels, should not leak. Specifications, both as to high grade materials and careful design for this purpose, are exceedingly difficult to meet. Industrial research specialists are busily engaged in developing more efficient and yet reasonably priced pumps to meet this particular demand. Pumps are just one item that must be developed to a finer point in order to meet atomic energy requirements. Metallurgists have learned a great deal about corrosion of metals in the past few years—knowledge that is not only valuable to reactor technology but extremely useful in other fields and industries.

OTHER CONSIDERATIONS

Radiation Protection

Despite its beneficial attributes radioactive materials can prove harmful if not handled with due care. Some radioisotopes are injurious in relatively minute quantities if inhaled, ingested, or otherwise taken into the body. Serious burns or death may result from exposure of the body to external radiation. The noxious characteristics of different radioisotopes vary. Polonium 210, for example, does not present a substantial radiation problem unless introduced into the body. High energy gamma emitters, on the other hand, may produce injury at a considerable distance from the radiation source. Unlike most deleterious agents there may be a considerable lapse of time following exposure before radiation effects become manifest. Genetic damage may not become apparent until many generations later.

A nuclear reactor, contrary to popular belief, will not support a nuclear explosion. The primary problem is one of preventing release of the gross quantities of highly dangerous fission products produced in reactor operation. These products are more toxic by a factor of several million than any chemicals or other dangerous material commonly encountered in industry. Several possibilities must be taken into account and safeguarded against in designing a reactor. If the reactor controls should fail it is possible for the power level to rise several thousand fold in a split second. Fuel elements containing fission products could be melted and released. An acute chemical reaction (as certain materials with water) could also result in release of fission products.

The probability of a significant accident with currently operating reactors, however, is minimal. Reactors for power and other civilian uses undoubtedly will incorporate several safety factors operating independently. A self-regulating type of reactor may be constructed that basically does not require control devices. As an added safety feature automatic control devices may be built in. If considered necessary the entire system can be enclosed in a safety envelope or shield to contain fission products in event of reactor failure despite other safety features.

Growth of the atomic energy industry has been attended with commensurate appreciation of the harmful effects of ionizing radiation. The safety record in this and other countries has been excellent. Continued conservatism and realistic respect for this highly useful but potentially harmful force will safeguard against untoward incidents or radiation injuries which have been held to a minimum thus far. If continued emphasis is placed on radiation safety it is unlikely that atomic energy with its vast rewards will become a "Pandora's Box."

Atomic Energy and Education

The rapid growth in the use of atomic energy has served to emphasize the need for more trained physicists, engineers, chemists, technicians, and other scientific personnel. There is a marked need also for well-trained and adequately compensated science teachers to convey the necessary knowledge at a high school, college, and graduate level. Continued progress in development of atomic energy depends upon adequate professional and technical manpower.

Only a small number of colleges and universities offer formalized courses in medical use of radioisotopes, radiobiology, radiochemistry, and related subjects. Science teachers are frequently drawn from the teaching profession because of more attractive salaries in industry. Those that remain frequently are not able to devote full time to science subjects. Conversely, many specialists in other subjects are compelled to teach science courses for which they are not equipped.

It is encouraging, however, to note the increasing number of schools that are including nuclear science courses as a part of the required curriculum. It is interesting to observe also the number of high schools that are making use of low-level quantities of radioisotopes in classroom experiments and demonstrations. Of even greater interest is the number of young scientists, enrolled in schools offering no nuclear science courses, who write the Atomic Energy Commission seeking further knowledge of atomic energy.

The Atomic Energy Commission is aware of the growing need for trained personnel and is lending assistance in meeting this need. The AEC offers fellowships in radiological physics, industrial hygiene, and industrial medicine, and provides extensive on-the-job training. More than 2000 graduate students are doing research in connection with AEC research contracts. The AEC also plans to expand the preparation of materials suitable for teaching purposes at various levels. More than 2000 persons have completed the course in basic techniques of radioisotope handling sponsored by the AEC and offered since 1948 by the Oak Ridge Institute of Nuclear Studies.

Assistance is offered to nonprofit and educational institutions in obtaining and operating research reactors, the AEC waiving use charges for special nuclear material, assisting in fabrication of fuel elements, etc. Similar assistance is offered in the case of subcritical reactors or assemblies which are valuable training aids. The AEC offers a one-year graduate level course in reactor technology at the Oak Ridge National Laboratory and at the Argonne National Laboratory. A special course for college faculty members is held each summer at the AEC's Argonne National Laboratory, and at the Brookhaven National Laboratory.

Although the immediate need is for more technical personnel there is little question that some knowledge of atomic energy should be imparted to all students. An increasing number of administrative and management officials, for example, will be presented with potential uses of atomic energy and required to make appropriate management decisions. Businessmen, lawyers, and other professional persons must learn the language of the atom and gain some appreciation of its effect upon society.

The United States has demonstrated a marked interest in sharing its knowledge of the peaceful atom with other countries and assisting their scientists to acquire requisite training. Thirty students from 19 countries, for example, were enrolled in the October 1955 School of Nuclear Science and Engineering operated by the AEC's Argonne National Laboratory. At this same time 31 scientists from 21 countries were enrolled in the radioisotope techniques course of the Oak Ridge Institute of Nuclear Studies. Many more foreign students are securing training in radiochemistry, nuclear engineering, radiological health, physics, isotope techniques, nuclear instrumentation, atomic and nuclear physics and related subjects, in more than 70 colleges and universities in the United States.

Atomic energy is universal. Practical utilization of this unparalleled force for mankind depended upon the individual and collective efforts of scientists from many countries: John Dalton, J. J. Thomson, E. Rutherford, F. Soddy, James Chadwick of England; W. Roentgen, Max Planck, Hans Geiger, Otto Hahn, and F. Strassmann of Germany; Henri Becquerel, Louis De Broglie, F. and Irène Joliot-Curie of France; Niels Bohr of Denmark; A. Einstein, Arthur Compton, C. J. Davisson, L. H. Germer, E. Fermi, E. O. Lawrence, G. T. Seaborg, I. Perlman, H. C. Urey, and J. R. Oppenheimer of the United States, to name only a few. It is only proper, therefore, that this great force, unleashed and harnessed by the scientists of many countries, be applied for the benefit of all mankind.

Fifty-one nations, thus far, have received radioisotopes produced in the United States. Among other countries and uses AEC produced radioisotopes have been employed for treating leukemic patients in Argentina, autoradiographic studies in Denmark, instruction in radiobiological techniques in France, treatment of hyperthyroidism in India, therapy of malignancies in Japan, fertilizer studies in New Zealand, plant growth research in Norway, studies of sulfonamides in Switzerland, study of rickets in Sweden, research in enzymatic processes in England, labeling of mosquitoes in the study of jungle yellow fever in British West Africa.

Radioisotopes have contributed to the development of better steel, aluminum, and other metals, superior plastics, lubricating oils, drugs, fertilizers, fungicides, hardier crops, improved detergents, better tires, textiles and paints.

Future decades undoubtedly will reveal many more uses of atomic energy. Undeveloped countries, handicapped by inadequate supplies of fossil fuels, may progress more rapidly as atomic power becomes a reality. A large merchant fleet with practically unlimited cruising range and greater cargo capacity may become a reality. We can also visualize atomic propulsion of ocean liners, airplanes, and possibly locomotives.

We have received substantial dividends from our investment in atomic energy. Only time, however, will reveal the full impact of atomic energy upon society and its contribution to the world economy and general welfare of mankind.

❧

PART THREE

CHAPTER IX

Science and Society

Intellectual and Social Implications of Science and Technology for Democracy

CHARLES W. MERRIFIELD

THE BURDEN of the chapters in the preceding sections has been to make explicit for teachers of science and social studies a central theme: Science and its associated technology is an instrument of social change. Not only have science and technology *caused* human cultures to change and adapt themselves, but it has caused them to change faster as scientific know-how has accumulated. In anticipating "The Fabulous Future" of the United States looking toward 1980, Mr. David Sarnoff, Chairman of the Radio Corporation of America says:

> The dominant physical fact in the next quarter-century will be technological progress unprecedented in kind and in volume. In relation to the total history of the human race, the last hundred years have been no more than a split second. Yet they have compassed more technological achievement than the millennia that preceded. The harnessing of electricity to the purposes of light, power, and communication; the demonstration of the germ theory of disease; discovery and application of the electron; invention of radio and television; development of anesthetics; the exploration of genes and mutations; invention of motor vehicles; evolution of the assembly line and other mass production techniques; proliferation of organic chemistry; the splitting of the atom; development of antibiotics; the vast expansion of the known and measured universe of stars and galaxies—these are only the highlights of recent progress.[1]

But what is even more important is that technological innovation is proceeding at an increasing speed. "It is not a case of continued increase," Mr. Sarnoff states, ". . . but of continued acceleration of increase. We need only project the curve into the future to realize that we are merely on the threshold of the technological age."[2]

To a few teachers this prospect, which is not a flight of fantasy but based on sober and careful analysis of past and present scientific progress, may be a bit frightening. But to many more it is becoming a recognized fact that understanding the progress of science is more and more an indispensable tool of good teaching and of the master-teacher. Other chapters in this Yearbook are evidences in themselves that no longer can the teacher of science or social studies remain indifferent or unconcerned about what is happening to the "fact-base" of the world in which all of us must live.

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[1] Sarnoff, David, "The Fabulous Future." *The Fabulous Future: America in 1980.* Introduction by the editors of *Fortune*. New York: E. P. Dutton & Co., 1956. p. 14-15.

[2] *Ibid.*, p. 15.

Change, of course, is going on about and within us human beings ceaselessly. It is quite unreasonable to suppose, at this writing, that anything men can do will stop change. Some of it can be comprehended by men; much of it remains yet to be explored, classified, and combined, or recombined by men into fresh, new knowledges. This is what the "way of life" called science helps us to do. It helps us to make friends with change, instead of shuddering at its prospect. Science helps us investigate in an organized fashion the "causal" connections of the worlds we live in and the worlds which live within us. Through science, we gradually become more able to predict change with reasonable accuracy (probability), and thereby it becomes more and more possible to organize human institutions and customs in accord with the patterns of change which have been discovered thus far. And, as Mr. Sarnoff indicates, the human beings of the planet are only on the threshold of this chapter in the human enterprise.

But when we speak about *science*, as such, it is well to remember and keep clearly in mind what it is we mean by it. It means at least three things. Science is a *way* of making inquiry into change. It is also a method which has *products;* that is, applications like the compass, or the printing press, the adding machine, television and nuclear power. And, it is also a *philosophy*, a view of the world in which we live, using basic assumptions about reality and knowledge and human nature which are different in kind from those of most of the intellectual tradition. The various chapters in this Yearbook exemplify these three coordinate aspects of the cultural "way" called science. Part I has dealt with the history of science as a method and analyzed the manner in which scientists work with change. Part II has considered a number of case studies in which science has been applied to human problem-areas and surveyed some of the institutions in the United States created specifically to press forward the technological frontier. The present section, Part III, seeks to gather up the implications of foregoing chapters and to focus them on yet another field of application—the contributions of science to a democratic philosophy of education.

HOW HAS SCIENCE CHANGED HUMAN SOCIETIES?

Science as a Method

In his brilliant book called *Man Against Myth,* Barrows Dunham recounts in the Preface a conversation of his son Clarke and friend Tommy, another nine-year-old: "Your father's writing something?" asked Tommy. "Yes." "What's the story about?" "It isn't a story; it's about social superstitions." Tommy pondered this awhile. Then he said, "Gee whiz."[3]

It is really with something of this kind of feeling that one reflects on the proposition that no age truly knows itself because it is unaware that some of what it believes is superstition. Tommy was only expressing a common wonderment which often accompanies the uses of scientific method, as it continuously reveals to us inadequacies of our present ways of believing, thinking and acting.

Professor Dunham lists 10 "social myths," for example, in which people have believed and used at one time or another to organize social institutions and relations:

1. You can't change human nature
2. The rich are fit and the poor unfit
3. There are superior and inferior races
4. There are two sides to every question
5. Thinking makes it so
6. You cannot mix art and politics
7. You have to look out for yourself
8. All problems are merely verbal
9. Words will never hurt me
10. You cannot be free and safe.[4]

To such a list might be added other examples: The world is flat; Disease is caused by demons; Man is born evil; The earth is the center of the universe; Poverty is the inevitable condition of progress; Two plus two always equals four; Man was not made to fly.

What has caused us to change our minds about such dicta? What *causes* us to shift from one set of actions and one set of institutions to another? Whence comes the impelling reason to change? Indeed, what has changed in order to make it possible for men to alter their beliefs?

The answer is illuminating because it demonstrates the manner in which the methods of science serve man by changing his views and outlooks. The central thesis of scientific methodology is *the substitu-*

[3] Dunham, Barrows. *Man Against Myth.* Boston: Little, Brown & Co., 1947. Preface, p. 2.

[4] Dunham, Barrows. *Man Against Myth. Passim.*

tion of experiment for inherited authority as the basis for testing truths. This amounts, of course, to a revolution in human thought, and it contains the basic assumption science makes about the way knowledges are constructed, not "found." In substance, science says: We *know* what we know only because it is the outcome of experiment, that is, because the observed consequences of deliberate experimentation provide the surest way men yet have to discover and use the patterns of process and change.

This is a very humble and self-restrained view of knowledges. It forbids the scientist to accept other than that which can be demonstrated openly, over and over again, for anyone to see, test, and controvert if he can. The scientist uses doubt as an indispensable professional tool or instrument to guide him in asking questions on which experiments may be constructed. He treats the discovery of error as a positive good because it tells him what *not* to do the next time. Negative results are as important as positive results. Moreover, he is unwilling to indulge in obiter dicta, conclusions which are not actually contained within the data he has gathered to test his hypotheses.

But when the scientist *has* reached conclusions, he has literally changed the conditions of human life by adding a new increment to older (relatively static) situations. He has introduced a yeasty factor (new knowledge), which, as it spreads into public comprehension, constitutes a new potential for reconstructing human relations. Eventually, the possibilities in the new additions to knowledges come into possession of those who exercise the sovereign functions of a society (whether they be one man, an oligarchy or all the people). When this happens, social change (that is, institutional change or modification) is more likely to take place. Sometimes the sovereigns may bitterly oppose changing the human outlook, as in the case of Galileo's assertion that the sun was the center of the universe. Sometimes change may be fought off and delayed for years and decades, as may be the case of the United States Supreme Court's decision of 1954 that "separate but equal" treatment of different races was no longer a constitutional way of handling the educational function in a democratic society. But sooner or later, generation by generation, the human family has tended to make use of its knowledges and given its consent, often reluctantly, to living in accord with what has been discovered. To this all the evidences of history testify.

The methods of science might collectively be likened to an organized irritant. This is so because science substitutes curiosity for complacency, deliberate encouragement of doubt for uncritical acceptance of things as they now are. The scientist's motto might be stated: Things might be better than they now are; let's look and see! The methods of science are deliberately aimed forward in time. The scientist's interests and his methods are projective and anticipatory. He is engaged in an emergent future, as he seeks to establish new "causes" for things yet unknown. What he produces in the way of new discoveries, new technological applications, and new ideas gives human societies new horizons of action and accomplishment.

Science and Its Products

Not only does scientific methodology change man's concepts about himself and his world; it gives him new worlds for old. By expanding the technical means of organizing human experience, and by demonstrating new ways to resolve pressing problems, science changes the "fact-base" in which human societies exist.

Peace, for example, once an ideal dreamed of by men of goodwill everywhere and in every age, now becomes a stark necessity for survival in an era of mass-destruction and missile warfare. Someone has suggested that the present age be called the "Age of Radiation." The technological possibilities of nuclear fission have suddenly, within the last decade, forced mankind to face up to the fact, as Robert Sherwood says, that ". . . the very aspiration to life itself may be blasted any one of these days into radioactive rubble."[5] To which President Eisenhower added, while addressing the United Nations:

> . . . the defense capabilities of the United States are such that they could inflict terrible damage losses upon an aggressor [but] to stop there would be to accept helplessly the probability of civilization destroyed. . . .[6]

In this case the products of the scientific laboratory have changed many of the basic, inherited calculation factors of statecraft. No future generation can safely neglect the technological possibility of species suicide, and total war has overnight become a luxury no one in the world can afford. Humans are still getting used to this fact.

Less spectacular, perhaps, but equally significant for human societies are the products science has given men to serve them in the economic functions of obtaining access to the means of life and experience. Modern industry, for example, could hardly be conceived in the absence of the wheel (a scientific contribution of primitive man), the lever, mathematics, the steam boiler, or the principle of interchangeable parts. Modern commerce could not even be imagined without an arabic number system, or the double entry bookkeeping system or the calculating machine. Modern entertainment industries would be a flight of the magician's fancy without electricity, microwave transmission and the lens and camera. It would be almost impossible to imagine democracy without the printing press, universal free education, the concept of the consent of the governed, and unity *through* diversity, not conformity. America itself might still be an undiscovered wilderness without the ocean-going sailing ship, the astrolabe, and celestial navigation.

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[5] Sherwood, Robert. "There Is No Alternative to Peace." *The Fabulous Future. Op. cit.*, p. 147.

[6] As quoted in *Ibid.*

In countless ways, in physical and social fields, in the arts and humanities, and in communications, the products of science open new possibilities. And by so doing, they tend to introduce new factors into human relations. They are like yeast in a loaf of bread, changing the shape of the ingredients, lifting them above themselves, letting air and light into the nooks and crevices. The actual presence of new ways of expanding the range of human choices by practical know-how is a kind of "forcing bed" of social change. Like plants in a seed frame, human beings can be encouraged to grow where there is light, water, and warmth. And the power of new possibilities has proved to be a lure which no generation has been able to resist.

When the products, the technical applications, of science make their way into public understanding, a curious phenomenon takes place. Human needs are adjusted to the new technology. In this sense, *invention becomes the mother of necessity*. One says: "We need a new television set at our house," or "the children need vitamins in a balanced diet," or "we need to share American know-how with other less-developed nations". What is the referent here for "need"? Where does the concept of necessity arise? The answer is clear. Without the technology of microwave transmission, without biochemical identification of bodily requirements or without the notion of world peace as mutual interdependence of nations on the best knowledges available, these "needs" would bear little relation to anything real and tangible.

It is a commonplace to say that man cannot do that which he doesn't know how to do. But when he *has* the know-how, the technological feasibility at hand to solve his problems, then, nothing can stop the power of tested ideas from coming into use. In this way, as the history of science so amply demonstrates, the invention phenomenon tends to reconstruct the mores of all cultures. Like secrets that can't be kept, new ideas and new techniques erode older belief systems, change human relations and slowly dissolve previous ignorances about the facts of environmental change. Just as an earth satellite opens an era of new possibilities in the conquest of space, and a new vaccine permits immunization of children against polio, so the future products of science, yet unimagined, may permit us to change our habits, see ourselves in new lights, modify our notions of what is "moral" or "immoral" and anticipate new horizons, new problems and new solutions.

Thus do the products of science transform human culture, finding their way gradually and ceaselessly into the social process through trial, acceptance and adaptation of men's social institutions.

Science as a Philosophy

Science and technology have changed human societies and promoted institutional modification through novel methods and novel products. But, almost unnoticed until fairly recently, a fresh aspect of science is beginning to exert an increasing influence in human affairs: the discovery that implicit in science is also a profound philosophy or "world-view." There is a growing conviction among many philosophers and scholars in many fields that eventually, perhaps, *science as a philosophy* will be far more important and influential in human society than simply as a method or the applicable products of that method.[1]

Especially in the last 100 years, roughly since Charles Darwin wrote the *Origin of Species* in 1859, attention has begun to turn more and more to the significance of the *way* the scientist works; not so much what he says, but what he actually *does* and the way he behaves when operating in the role of scientist. The philosophy of science is, perhaps, even more important to the teacher of science or social studies today, in 1957, than is familiarity with the methods and understanding of the impact of its products on society. Without at least a general understanding of the compelling and persuasive character of scientific philosophy, it would be difficult to teach meaningfully about either its methods or its products.

In order to understand something of the philosophic base of science, it may be well to delay our discussion of it until after a second dimension of the central topic, Science and Society, can be explored: those concepts and ideas emerging from science which can usefully be developed within the existing curriculum.

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[1] Cf. Ramsperger, Albert G. *Philosophies of Science*. New York: Appleton-Century, 1942. Bernal, J. D. *The Social Function of Science*. London: Macmillan & Co., 1939. Crowther, J. G. *The Social Relations of Science*. New York: Macmillan & Co., 1941. Dewey, John. *Logic: The Theory of Inquiry*. New York: Henry Holt & Co., 1938. Thornton, J. E., editor. *Science and Social Change*. Washington, D. C.: Brookings Institution, 1939. Oppenheimer, J. Robert. *The Open Mind*. New York: Simon and Schuster, 1955.

WHAT MAJOR CONCEPTS CAN SCIENCE BRING TO THE EXISTING CURRICULUM?

The teaching problem of how to fit "teaching about science" into the already existing curriculum is not an easy one for most teachers to resolve satisfactorily. Often, textbooks and courses of study are pretty well prescribed in advance, and deviations are discouraged. The "time-squeeze" needed to "cover the ground" seldom permits the addition of extra units of study, except perhaps with an exceptional group of students. And as every teacher knows, much instructional time is taken up in multitudinous duties of teaching good study habits, making announcements, maintaining classroom discipline and so on. To be quite realistic, therefore, the task of getting more about science into the present curriculum, even assuming its desirability, cannot be handled by displacing much of the content already there, nor by asking for any radical changes in current curriculum construction, activities or range of studies.

How then is it possible for the reader of this Yearbook to contemplate the introduction of anything more, including science, into an already overcrowded instructional program? Fortunately, the question is "academic." What is needed is not to add or subtract content, but rather a *different way of looking at* standard materials and methods already in use. If this be true, then the real problem is not insurmountable, and there is a solution which, though not easy, can make the teacher's instructional duties more meaningful and more satisfying than might be anticipated on the surface of things. Suppose we ask ourselves as teachers: What concepts emerge from the study of science by which the present curriculum in science and social studies can be enriched? At least four such concepts or tools appear promising:

1. Science serves man by enlarging the "fact-base" of knowledges about the worlds in which we live.
2. The basic functions of human institutions can be carried on (in any culture) more efficiently when the results of careful scientific experimentation are employed.
3. The method, achievements and ethics of science make possible a new way of regarding the relations of people in societies.
4. Science and technology do not result in any social utopias, but do result in the discovery of new problems, requiring further adjustments and further institutional changes.

For the sake of discussion, suppose the teacher of social studies or science determined to keep these four ideas in the back of his head as he approached his classes in the autumn. Suppose he said to himself: These are the *significances* about science and technology that I want to build into the learning experiences of this class. How can I do it without unduly disturbing the accustomed patterns, the lesson plan, the type of classroom method, the testing program to which both the students and I are accustomed? Can it be done?

CONCEPT I: *Science serves man by enlarging the fact-base of knowledge about the worlds in which we live.*

Almost self-explanatory and the easiest to illustrate, this concept explains the whole of the human experience on the planet. In its simplest terms, it says: Human life takes place in the context of continuous change, the principles of which are necessary to know in order to undertake intelligent action of any sort.

The teacher is, of course, engaged as a professional person in teaching the foregoing principle. His "course" is a *dis*course on the principles of his subject. His lesson plans or units are the logically identified parts of the whole. Each one is included (or others excluded) because they explain (or do not explain) some essential subprinciple or basic cluster of facts requisite to the student's understanding of the principles. The teacher of mathematics uses the theorem of Pythagoras in exactly the same fashion that the civics teacher uses the federal principle, because it is a tool or instrument which "relates" apparently unrelated or disparate facts into a usable generalization.

Science is devoted precisely to this kind of effort. From earliest man—taming fire or domesticating wild animals—humans have sought the unifying principles which explain the fact-base of a changing environment with which they have had to come to terms in order to live. Sometimes the solution was almost fortuitous; sometimes, as in more recent years, it has been deliberate and highly organized. But always the product has been the same—a continuously enlarging body of knowledges about the planet and its parts, cosmic and microcosmic.

Scientific effort of this kind has served man in many ways. Its precious gift has been "predictability." That is, by knowing how the facts of living-in-change have been related to each other in the past, men have ventured to *predict* that given the same or similar relations, the same or similar things would result in the *future*. Early man could predict, for example, with reasonable accuracy that the sun would rise the next day. But if clouds obscured the sun's rays, he had little recourse except to "explain" the phenomenon by going outside his actual experience and attributing it to the god's anger or displeasure or some other "cause" which remained unknown except by postulate.

Today, of course, the whole destiny of human life on the earth can be affected by the predictabilities which man has constructed out of his observation and experiment with the fact-base of life and change. Men's social institutions almost take for granted the germ theory of disease, which permits prediction that vaccine injected into the blood stream establishes immunity for an extended period of time. It is no longer seriously believed that irrational behavior can be attributed to witches, yet at one time (only 160 years ago) the village of Salem, Massachusetts gathered all its legal powers and the prestige of the state behind that belief, and acted upon it. The astrolabe, the compass, the ocean-going sailing ship of Columbus and Hudson and Cabral, helped men open a new chapter in world civilization by opening a new physical frontier, the New World. But the atomic-powered submarine and the great ocean liner of today still basically operate on the same kind of navigational and shipbuilding *principles*. The family of modern America takes for granted the automobile, and places a remarkable degree of faith in the predictability of its tires, its brakes and its efficient mechanical operation.

And so each generation is literally better prepared to make its way in a changing world because of past discoveries of principles which make the facts of the world stick together in predictable patterns. Such patterns of predictability serve human purposes, sometimes beneficent and sometimes evil goals. Dictators, for example, may use the methods and/or products of science for mass-killing, thought-control, and enslavement of the many by the few. But science and its products can also heal the sick, produce abundance, link continents, light cities and enlarge the freedoms of all the people. In fact, the meanings which men have attached to "good" and "bad" have often been taken directly from the ways in which knowledges have been used. When science is used at all, however, its utility depends upon its ability to achieve predictability, based on pattern in a world of constant change.

There are few, if any, courses in the standard curriculums which do not employ this concept, at least implicitly. Every teacher of any subject is professionally trained to "predict" that some subject-matter (or certain learning activities, or methods) are "more likely" to educate than others. Why not, then, include students in the fascinating game of prediction? The wise and discerning teacher of science or social studies can find many ways to illuminate *what* is being taught by also explaining *why* it is being taught. When students understand why they learn the separation of powers in Civics, or Bernoulli's Principle in General Science, their learning is much more likely to be permanent and meaningful to them.

Patterns of predictability serve not only the school, but every other social institution. The family, the corporation, the labor union, the church, the military, government and the world society—all must anticipate and plan for the future. All of them build their futures upon some notion of what the facts of life-in-process are, and upon some set of principles (or theory) which relates facts coherently to one another. Occasionally, as Professor Dunham explains, these theories are wrong as proven by later inquiry; sometimes they need refinement and further study. But always there is need for a factual base for prediction. To the extent that science constantly produces new knowledges by enlarging the fact-base, it serves all of mankind's social institutions.

Concept II: *The basic functions of human institutions can be carried on (in any culture) more efficiently when the results of careful Scientific experimentation are employed.*

All of us live in a forest of social institutions. From the moment of birth, we become members, playing differing roles of a host of social groups: our families, the neighborhood gang, the school, athletic teams, clubs, political parties, military organizations, churches, and so on. From such human groupings, there is no escape if we are to continue to live in society with our fellow creatures. It is this basic fact which introduces a second concept useful for teaching about science and technology within present school and college curriculums.

Institutions are organized patterns of human behaviour. They tell us what we may do and what we may not do. They prescribe and proscribe our daily lives in almost every particular. They are the agents or tools of any human society. Their reason for being (and their justification for existence) is always the claim that they carry on some necessary function without which society could not do. The duty of institutions is to carry on the assigned function or functions in as efficient a manner as possible, within the cultural mores and values of a given culture at that stage of its development.

But what is the "most efficient" way of carrying on the basic social functions? What is meant by "efficiency"? Does the meaning of "efficient" change, and, if so, under what circumstances?

As we have seen in the foregoing discussion, scientific methods enlarge the fact-base of human knowledges. They produce a social yeast which, when its significance comes into popular understanding, changes the social climate in some degree. What is likely to happen to social institutions or to the existing "rules of the game" when this happens? To find out what may happen, it is essential that students of society make a basic distinction between the *functions* of institutions, and the *structures* of institutions.

The science laboratory, let us say, is created to perform the function of controlled experimentation. On its staff are a certain number of senior professors, a Nobel Prize winner consultant, so many laboratory technicians and assistants, a financial manager, and a janitor. The human "structure" of the laboratory, that is, the "array" of presumed skill and competence ranging downward from the higher echelons to the janitor is highly significant. It tells us that the *instrumental* function of controlled experiment can be most efficiently carried on when certain *ceremonial* patterns of rank, prestige and authority are observed. These patterns "grant" or "direct" or "enjoin" (with social sanctions) certain persons to do certain things, and only those things. The Nobel Prize winner may not sweep the floor; the technician may not decide how to spend the funds; the business manager may not direct the experiments, and so on.

Such arrangements are observable in all social institutions and they are always based on the *assumption that the existing structure* is *the most efficient way of performing the function assigned.* Every war veteran is familiar with the hierarchy of prestige and power in military organizations. Anyone who has had experience in business firms has noted the same phenomenon, arraying people in echelons of status from president to office boy. The basic question is, of course, not that such arrangements exist, but whether the existing power-structures are in fact using the most efficient knowledges and skills at hand to carry on their respective functions.[8]

What appears to be the case in every social institution is a possible confusion over what "efficiency" actually means. On the one hand, there is an *instrumental* criterion for judging efficiency: getting the job done, solving the problems, performing the functions assigned in keeping with the best know-how available. On the other hand, there is the *ceremonial* criterion: the conservation of the existing *status quo,* nondisturbance of the prevailing power-structure of rank, authority and prestige, and the enhancement of the social "standing" of those who currently hold discretion over the lives of others in that institution.

It is obvious on brief reflection that these two standards for judging social efficiency are in perpetual competition with one another. One, the instrumental, reflects the tool-and-idea using potentialities of men; the other, the ceremonial, reflects human desire for stability, equilibrium and finality. The instrumental standard is dynamic, forward-looking, status disturbing, evocative of change. The ceremonial standard tends to be static, tradition-oriented, status-conserving, fearful of change. The instrumental activities of institutions offer us a way of judgment built up out of creative intelligence, curiosity and experiment. Ceremonial activities offer us a criterion of efficiency arising ultimately from a nonmaterial set of values, often mystic and usually interpreted through the power of "personality." Human beings participating in institutions constantly face a choice between, or at least an effort to accommodate, these two radically different ways of viewing the efficiency of social life.

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[8] This distinction between kinds of institutional activities may be called the Veblenian distinction, after Thorstein Veblen, one of the seminal minds in American social science. For an excellent summary of Veblen's thesis, see: Ayres, Clarence E. *The Theory of Economic Progress.* Chapel Hill: University of North Carolina Press, 1944, p. 99-102. Cf. also Chapters 6, 7, 8, 9.

Such a situation is neither deplorable, nor honorific. It is simply an historical fact that human societies are pulled both forward and backward; forward by organized intelligence (science) and backward by habit, mores, and tradition (non-science or pre-science). It is also a fact—perhaps the most significant fact in human history—that as knowledges have enlarged throughout the centuries, the instrumental-scientific type of experience has tended to *replace* reliance on ceremonial-mystical foundations of thought and practice. This has been so because humans have tended to choose technically demonstrable instruments to help them resolve their problems, rather than rely upon the assurances of some distinctive "elite" for social guidance and wisdom. This Yearbook is one unique testament to this general proposition.

Almost every teacher of science or social studies already teaches (perhaps only implicitly) what has just been stated. It is virtually impossible to teach science, biology, chemistry, physics, mathematics, physiology, astronomy, or any other branch in this general area without dealing explicitly with these instrumental tools men use to render intelligible the physical environment. Likewise the teacher of geography, civics, world history, social problems or any other field of social analysis can hardly evade the great lesson of the human story: the growth of population *and* freedom as the technologies for both gradually became known and used. Here in the United States, where a mixing bowl of many cultures was stirred up in a space-land frontier, there resulted a continuing "rubbing together" of customs and imported ways of carrying on the necessary social functions. Out of this abrasive action of theory and practice has emerged a kind of "forcing-bed" phenomenon in which borrowed ideas were recombined in new ways, new frontiers of human thought were opened and occasional "breakthroughs" in research were achieved. The story of the United States is, in great measure, the story of a creative search for the instrumentally efficient ways of carrying on the life functions.[9]

In some such way, science serves men's institutions by providing them the technical means of "instrumenting" their functions. Science helps us to distinguish between the ceremonial and instrumental views of progress. To science, progress is a function of using tools knowledges are tools) and science *uses* them to experiment with better ways of better living. In this sense of efficiency, human institutions can function better when they employ the fruits of science and technology.

Concept III: *The method, achievements and ethics of science make possible a new way of regarding the relations of people in societies.*

The popular concept of "the scientist" is interesting testimony to how little science is comprehended even within the commonsense of the United States. The scientist is often pictured as a "longhair" or "egghead." He usually falls far short of standard ideals of beauty; he may be forgetful, preoccupied, unskilled in money matters and ill at ease in social settings requiring small talk and simulated gaiety. And if this seems to be an unkind caricature, we may remember that Professor Albert Einstein was all of these things.

Yet Dr. Einstein dominated his generation as few men have in their own lifetimes. His succinct letter to President Roosevelt in 1939, warning of the urgent necessity to proceed with nuclear fission research and its subsequent results in the wartime Manhattan Project, changed the course of modern history. To Dr. Einstein's uncomprehending amazement, however, people came to adulate, praise, thank and almost to worship him. As long as he lived he suffered this public adulation without understanding why anyone should even bother to remark about what to him was the distinctive mark of *all* human beings: inquisitive, free-ranging curiosity about man and his common environment.

Dr. Einstein's feelings are of importance to teachers, indeed to all citizens of a democracy, because they suggest the kind of honest reappraisal of the relationships of people as a way of living which becomes possible when one examines the philosophy and practice of science.

In the first place, the scientific procedure profoundly shifts the basis upon which an individual's rank, prestige and status are calculated. All of us are quite familiar with common "indexes" of social status. They include: (a) wealth, (b) birth or ancestry, (c) race, (d) religion, (e) age (seniority), (f) sex, (g) national origins, and many others less broad and much more subtle. But to science these are irrelevant. Orthodoxy of behavior, conformity to ceremonial niceties and other automatic indexes of social standing are only slightly germane to the problem-solving function, if at all. When it comes to determining causal connections in the scientific-social world, other attributes of quite a different kind appear to be required. Whether one is unprepossessing or diffident in social company, whether one is poor, or shy, or elflike (and Professor Einstein was all of these) makes but minor difference in the qualities of the scientist's work. The common attributes of what is usually thought of as the "great man," dynamism, personal charm and magnetism, persuasiveness, competitiveness, cunning, facile manner—these seem to be of profound unimportance to the man of science.[10] Why is this so? What qualities of individuality does science require, and how do such qualities affect human relations in a democracy?

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[9] Cf. Moore, Bernice L., and Harry E. "What Is Creative Living in Modern America?" *Educational Leadership* 14:26-33; Oct. 1956.

As the foregoing has suggested, science follows a unique general method of organizing human experience for human use. That method is open, nondogmatic, and flexible enough to account for continually changing and accumulating evidences. There is nothing mysterious about it, no mystic aids are invoked, and it tends to carry its own conviction along with it. Knowledges in science do not depend upon exhortation. All the while, attention is drawn to human fallibility, to the likelihood of human errors (whose detection is a prime aim of science), and to the need for constant checking and rechecking. Accuracy, relevance and humility, science holds, can never lead to absolutes or to "certainty," only to varying degrees of probability.[11]

And so it is extremely difficult in scientific procedure to carve out special individual "kingdoms of exclusive intelligence." For its proofs, science depends upon the independent verification of a whole fraternity of scholars and technicians, intent upon causal explanation of various phenomena. Such a system does not lend itself to social dictatorships, or to worship of "personality" as *the cause* of happenings or conditions. To science, personality causes nothing, even though individuals are involved constantly in the process of change which they are observing. What is of supreme importance to any scientific enterprise is the freshness of imagination which can generate new hypotheses that relate previously unrelatable data—skill in organizing and arranging data for testing purposes, unflagging curiosity, perseverance and willingness to repeat, recheck or reshape experimental procedures, and the personal humility to accept and use mistakes and errors constructively.[13]

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[10] This is not flattering, of course, to the "great man" theory of history, nor to a good deal of our social tradition which attributes causality to "leadership," or "genius," or other mystic potencies. These are interesting fireside folk-tales which seek to account for progress; but they are not germane to the actual painstaking, persevering combination of tools and ideas or to the requirements of demonstrable proof or to the elaborate care in checking conclusions, nor to the humility and self-restraint in offering alternatives, all of which are characteristic of science.

[11] Cf. Boyer, Francis. "The Research Personality and The Research Process." *Chemical and Engineering News* 28:1639-40, 1702; May 15, 1950.

This is a concept of social leadership which still seems strange to many people. It is a leadership based upon *knowledges from experiment,* not upon the proving of personal worth by establishing discretion over the behavior of others. Real power, says science, is the power of ideas and tools.

Another contribution of science to social relations follows from this concept of leadership. It is a new way of approaching the ideal of freedom of the individual. Freedom has long been an ideal of democratic peoples. Usually its meaning has taken shape in the struggle to be "free from" the kinds of power some men have traditionally wielded over the lives of the many. So freedom in its historical sense, often refers to the "liberty of the individual"; to his wish to be free from arbitrary and irresponsible power. In the United States, a good example of this wish to be free can be seen in the assertion of the American Declaration of Independence that men are *born* free, and possess certain "unalienable" rights, whose protection is the main function of government.

But if the findings of science are reliable, no man can be "free" from the responsibilities of living in a world of change and process. Personal freedoms are always hedged about by certain restrictions of culture and custom, by the civil rights of others, by the fact of living in change, and especially by what men do not yet know. It is in this latter area that science serves men best. By enlarging the "fact-base" of human knowledges, the practical effect of scientific method and technology is to *enlarge the real alternatives, the actual choices,* of men. Men are freer when they have more actual choices. We are freer today than any other generation that has ever lived, not because the present generation is any more intelligent or brilliant, but simply because we can build upon what previous generations discovered. Our present freedoms involve an unpayable debt to the whole cumulative organized experience of the human species.

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[13] *Ibid.*

Freedom, therefore, as an ideal is related to scientific procedures as ends are related to means. Science provides the intellectual-technical means of achieving freedom. But it is a freedom of choice between alternative ways of behaving, not the somewhat naive concept of gaining individual liberation from everything which would block personal whims and fancies. In social terms the latter could lead only to license and anarchy. Meaningful freedom must always be responsible to the facts, as science constantly demonstrates. The problem of human society, therefore, is not a conflict between freedom and "authority," but constantly to draw the distinction between *responsible* freedom and authority and *irresponsible* freedom and authority. Science serves us well when it helps us to make this distinction between freedom and authority based on instruments and tools, and freedom *versus* authority based on ceremonial criteria, such as wealth, race, religion for determining who may be free and who may exercise authority.

For the teacher of science or social studies, there is, perhaps, no more fundamental lesson to be learned from science than the following. In the teaching and learning process, to give a student the scientific approach to responsible freedom is to provide him with one of the essential tools for democratic citizenship. Like the rest of us, every student must make choices but the essential skill in choice-making is to be able to identify *why* one selects the pattern of behaviour he does. Science is eloquent to us, as teachers, in this regard. It offers us a tried and tested standard of judgment, backed by the whole of the human experience. And the consequences can be studied throughout human history. Those consequences tell the story of gradually expanding ranges of choices which increase the freedom of the individual. Freedom to choose responsibly, not freedom to do as one pleases, is the lesson and practice of science.

CONCEPT IV: *Science and technology do not result in any social utopias, but do result in the discovery of new problems, requiring further adjustments and further institutional changes.*

Every age dreams of the time when it can put away the cares of the world, stack its tools up in the corner and live without working. Sometimes this is called "retirement," or nirvana or just plain heaven. Science has been praised and its products prized very often because it seems to be leading us in these directions. And no one could deny that science helps us to greater leisure, greater enjoyment of experience, greater abundance and more secure living. But science, by its cultivation of curiosity can never be "finished business." There would seem to be no prospect for a science utopia, where all change stops and perfect equilibrium begins, now or in the eventual future. Though, perhaps, disappointing to some, it is apparent on brief recollection of the ways of science, that dreams of an ultimate utopian society are fanciful indeed.

Science is never-ending like time and process, and change and development into which it is designed to inquire. Where scientific methods are employed to resolve one problem-situation, two, six or a dozen more problem-situations are likely to sprout. Students first confronting this phenomenon are likely to ask: Why, then, try to solve any problems at all, if all you get is another set of problems you didn't know existed? That is a fair question and the wise teacher should be prepared to answer it candidly and completely.

The basic fact of all life is change and process. There is no foreseeable end to it. Such being the fact, human beings have no recourse except to adjust to it and if at all possible to make friends with change so that human beings can learn how not to be afraid of it.

This adjustment is not easy in most cultures. The pioneer in any field must face the opposition of those who would arrest the social process and keep things as they are. The imaginative inquiry of the free-ranging intellect has always been a dangerous occupation. Socrates, Jesus, and Bruno were respectively poisoned, crucified and burned at the stake. Galileo was forced to recant on his knees in Rome. Thomas Hooker, Roger Williams, and Anne Hutchinson were exiled from the Massachusetts Bay colony. Peter Zenger, Elijah Lovejoy and John Brown were deprived of livelihood or life; the great Condorcet died on the guillotine; and in recent memory independent thinkers have lost their jobs, been imprisoned or suffered attacks on their good names because their views of the evidences did not meet the rigid standards of social conformity. But, though the ways of preserving the *status quo* can sometimes be cruel, they do not seem able to prevent new knowledges from coming eventually into broad human understanding. Jesus' view of social ethics did not die with him, but flourished and grew into a widely supported approach to human relations. Galileo's proof of the heliocentric universe is now fully accepted even by its original opponents; the free press championed by Peter Zenger is a cornerstone of democratic political behavior everywhere, and Elijah Lovejoy's and John Brown's dream of a polity open to men of all races is an accomplished fact in American constitutional law.[13]

[13] For an illuminating discussion of present-day "closed areas" of social studies content, see: Hunt, Maurice P., and Metcalf, Lawrence E. *Teaching High School Social Studies*. New York: Harper and Brothers, 1955. Chapters 11-16.

The power of ideas is processional. Even as successive generations "get used to" those ideas which were called subversive by their grandfathers, the process of accumulating still further and deeper knowledges does not end. The airplane and the television require new social disciplines; findings in educational psychology evoke new problems of arranging the learning process; nuclear warfare changes both the theory and practice of statesmanship; automation uncovers new problems for labor and management; eventually, perhaps, space-travel will confront us with yet more far-reaching adjustments almost unimaginable today. There are no "ultimate" resting places, no "finalistic" ends or goals, no "absolutes" which can be conceived of in the scientific framework. The social effects of this way of thinking are quite startling, yet it is essential that they be understood by the generations growing up in an age like our own.

One effect is to discourage "ism" thinking. "Ism" thinking is the type of social thought which insists upon adding the suffix, -ism, to root nouns like commune(ism), or capital(ism) or social(ism). Ism thinking tends to lead us in circles because it assumes its ultimate (perfect) goal before looking at the evidences. Isms are disguised utopias, and they are a snare and a delusion long suffered by many generations. Much of our social theory has been of this kind in the past. Many of our social "scientists" have made the mistake of becoming apologists for some sort of "fixed" social order, without really becoming aware of, or examining closely, fundamental assumptions which they had uncritically accepted. Karl Marx's assumption of inevitable class warfare was such an assumption, but one which only part of the evidences confirms. The doctrine of "natural rights" (sometimes stated as a "self-evident" truth) falls in the same category of unprovable assumptions. Racial superiority or inferiority, the notion of money-funds as the *cause* of progress, the "great man" and the "life-cycle" theories of history are other examples of basic assumptions which do not take into account all evidences, or are merely alleged principles which may be advanced by some in order to control the lives of the many.

No matter how well utopian thinking may be disguised, however, its foundations appear to be dissolved gradually by the kind of inquiry we have been calling scientific in this Yearbook. Such analysis insists that even basic assumptions find foundation in the run of evidences. The effort to sift out the instrumental (evidential) from the ceremonial (mystic) as a basis for social beliefs is, in the present age, beginning to take us toward a new concept of social democracy, and the task of social education assumes new significance.

Science is beginning to change the "fact-base" of education for citizenship. For example, in a democracy where emphasis is placed upon the making of wise choices by its citizens, the quality of those choices rests upon the extent of knowledges and real alternatives open to them. In other words, the fuller the understanding of the potential results or consequences of a given choice of action by the citizenry, the more satisfactorily can social problems be resolved. But when part of the evidence is withheld, when "secrecy" takes over as official policy, or when evidence is screened out which certain groups do not wish to admit as relevant, then, the quality of the citizen's choices is reduced in that degree.

We may call such a society a *crippled community*. It tends to cripple itself unnecessarily by permitting ceremonial standards to interfere with the problem-solving process. Most human societies have been crippled communities, including the present nation-states of our own day, as well as the world community in which we all live.

From one viewpoint, the task of scientific education is helping communities of men to uncripple themselves. Science and social studies courses are—or can become—highly effective instruments in this continuing enterprise. Properly organized, they can do incalculable and broadening good for young people. They can give young people opportunity to exercise their critical judgments, to learn the rules of evidence, to practice the construction of genuine experiments, to develop logical and fearless thinking, to begin to generalize accurately from particulars, to discover new problems, and to communicate without surrendering accuracy for impact.

Democracy and perfection are incompatible, because democracy is a process while perfection is utopia. Crippled communities are characterized by undue reliance upon the concept of perfection, despite the fact that all human societies must exist in a world, every particular of which is constantly becoming something else. Understanding these concepts is essential to teachers in democratically oriented societies.

The need of social education today is, obviously, for teachers of skill and experience, who can illuminate their subject-matter courses with scientific insights. It is not a question of adding or subtracting subject matter. What is required is that our teachers cultivate a broad view and a generalized understanding of the actual impact that "cumulative knowledges" have on human societies. Then, whatever is taught, is more likely to be taught in ways which really educate young people in and for living in democratic surroundings.

The Philosophy of Science and Democracy

We are now in a better position to return to the third way in which science affects society, namely, as a philosophy or a way of looking at the worlds in which we live.

From the foregoing, it can be argued that science gives a quite different view of human beings and their environment than anything which was articulately available to any of our ancestors. Especially in the last hundred years, roughly since Darwin, the main outlines of this new world-view are coming gradually into coherent shape. Two of the main guidelines of scientific philosophy need to be examined with some care, since they represent basic assumptions on which scientific procedures are constructed:

1. This world is a *real* world, peopled by *real* people, having *real* problems; reality can be experienced in fact.
2. Within this real world of experience, human beings can make *genuine* choices, having observable consequences.

One is inclined at first glance to wonder why such beliefs of science should be so important, or if anyone could seriously disagree with them. Actually, they would be heretical beliefs to most preceding generations. To assume, as science does, that reality exists here and now in everyday things, flowers, houses, people, ideas and technology, is to set aside a long-cherished belief of many of our ancestors that things of this life, on this planet, are merely *appearances*, or reflections of true reality, which exists somewhere out beyond mankind's reach. The idea of "absolute" perfection, truth, beauty, justice, love, and so on, has much vitality even in our own day. Against this, science places its belief that there is (as yet) no evidence whatever which proves the existence of such "essences," as Plato called them, and that *all* the evidences (thus far) give us adequate reason for considering that the word "real" can be used to describe human experience as we live it. Thus, science seeks to cut the "Gordian knot" of the appearance-reality dilemma, and treats it as characteristic of a stage of human thought from which we are now passing.

The other basic belief of science holds that in such a real world of unfolding experience, men have genuine choices whose consequences are open to inspection and analysis and, one hopes, to learning. The distinction drawn here is contained in the word *genuine* as applied to choice. The intellectual tradition is split between the idea that men have no choices at all, that they are merely pawns in the hands of an all-knowing Providence, or that, on the other hand, men have "free will" to do as they please. Science rejects both of these assumptions and, pointing to the evidences of the human story, invites attention to the fact that men's choices are limited by their knowledges, but once knowledges actually have been constructed, human choice widens out and makes possible options and alternatives which were not feasible before. Thus, says science in effect, genuine choice *is* open to men, but only on the basis of their being *responsible* for the consequences.

Any teacher can see at once that a world-view based on scientific assumptions exerts a profound influence upon the teaching-learning process. On a democratically oriented society, the impact is much less revolutionary than upon a society oriented to a single-authority system such as implied in any of the great "isms." In democracies, which are devoted to nurturing the dignity of individuality (not individual*ism*) and to the pluralistic (not monotheistic) construction of human judgments, the scientific assumptions appear to be uniquely suitable.

In fact the more one compares the fundamental premises of both science and democracy, the greater grows the compelling conviction that the one is the product of the other. Democracy, as a way of organizing human relations, cultivates responsible freedom of choice. Science, as a method and philosophy, produces the technical basis for making that freedom responsible. Democracy sponsors the continuous development of the uniqueness of individuality; science utilizes this uniqueness for producing fresh hypotheses, new viewpoints and the discovery of new problems. Democracy rests its foundations on the dignity of man as a responsible citizen; science makes possible the dignity of man by involving him meaningfully in the painstaking accumulations of reliable knowledges and their technical applications.

Science and democracy are like identical twins. They interact with one another, and in so doing help and serve man in the continuous adventure of reconstructing his life and his environment.

SUMMARY

This chapter has undertaken the responsibility for exploring the social and intellectual implications of science and technology for citizenship education in a democracy. The argument made may be summarized in the following propositions:

1. Science and technology are causal factors in changing human societies.
2. These changes flow from the unique character of science itself: as a method, from its products, and from its impact as a philosophical world-view.
3. The problem of how to teach about science and technology in already overburdened curriculums is not to subtract or add subject matter, but to illuminate what is *now being taught* by cultivating at least four major insights at whatever grade levels seem most appropriate.
4. Four major insights which can be used are:
    a. Science causes social (institutional) change by altering the "fact-base" of human knowledges.
    b. The instrumental standards of science permit human institutions to carry on their functions more efficiently than under ceremonial standards.
    c. In pioneering the instrumental view of human relationships, science makes possible a different kind of society based, not on the struggle for power, but on cooperative sharing of knowledges for solving real social problems.

   d. Science can neither promise nor achieve social utopias, but it can help man to organize his intelligence in such a way that the life experience is one of unfolding meaning, purposeful achievement, and continuing growth.

5. Viewed in this light, scientific contributions permit the actual fulfilment of the ideals of the democratic faith.

These social and intellectual implications of science reviewed allow a fundamentally different approach to civic education. It would appear both accurate and realistic to say that these implications can suffuse and illuminate what is presently being taught in science and social studies courses in the United States. The need appears to be to make explicit what is already in existing curriculums.

Perhaps the single and most central concept necessary to this task is the "character of proof" which science employs. In one sense it is the key to all the rest of the scientific philosophy. The self-limiting requirement in all scientific enterprise is that *whatever is claimed to be true is a causally demonstrable connection among actual evidences.* That is to say, anything for which truth is claimed must be open to negation, as well as to verification, in the run of the evidences. Such a claim must, further, be capable of open demonstration, to repetition, and permit testing in actual operations whose outcomes have been predicted in advance.

These are, indeed rigorous requirements, but they are as applicable to human societies as to test-tube laboratories and other human institutions. The process of democracy as described here can be thought of as the means by which human beings can test out what is true or less true or untrue. It may be that a society devoted to freedom and experiment is the best means we yet have for this purpose, but of this we are not sure. When democracy has been tested out in the world community as a whole, we shall have yet more evidence to bring to bear. And this world-wide testing is going on with increasing speed in the present generation. As it proceeds, there is all the more reason for the young people of this country to be pioneers in the effort. For they, after all, are the chief beneficiaries of science and democracy among the world's peoples, and their welfare—even their destiny—is involved in the outcome of the great experiment now going on. For teachers this presents both a fascinating challenge as well as professional goals of profound importance.

As teachers do begin to use scientific standards for education, they will begin to find the learning process in their classrooms taking on unsuspected dimensions. Instead of the daily routine of "inculcating knowledges" which seem to exist in, for, of and by themselves, these knowledges begin to be seen as instruments to achieve further goals, uncover new problems. Instead of the teacher having to play the role of "authority" in the classroom (a completely impossible role for anyone to fill) the basis for authority begins to shift to: "What are the evidences?" Instead of having to be a disciplinarian much of the time, the teacher finds it possible to become a resource-colleague of his students in a common learning adventure. And the classroom, instead of being simply an agent of social discipline, can become a group-process which pools ideas and skills and competences for growth in problem solving. Such a classroom, where intelligence is prized and stimulated, where choice-making is made responsible through practice, and all concerned learn to live and grow *together* is a social laboratory with close fidelity to the principles of democracy-in-being.

The remaining chapters of this volume are devoted to the more particular applications of the concepts developed heretofore in the chapters which precede them: to the elementary and secondary grade levels, and to institutions of teacher education.

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CHAPTER X

Science and Social Studies in Today's Elementary School

GLENN O. BLOUGH

TODAY it is possible to fly from where you are now to almost any spot on the earth in a comparatively few hours. You can telephone London, England, almost as easily as you can Saginaw, Michigan. You can heat your house, cool it, clean it, and light it by pressing a button. In other words, without belaboring the point, science makes aspects of today's living easy. Today, practically anything can be mass-produced and is. These are glimpses of our scientific world. Similar and more detailed descriptions of today's science-produced world are easy to find.

Throughout this Yearbook are scattered scientific words that paint a picture of today: fallout, automation, guided missiles, rockets, Salk vaccine, nuclear energy, H-Bomb. Consider the meaning of these scientific terms and you find yourself looking at the world of today—a world that is called the atomic age, the jet age, the machine age, and other names indicating that scientific discoveries dominate our way of life.

Science has substantially changed our lives and will continue to do so. Citizens of today are making and will increasingly continue to make, the decisions about the role of science in today's world. This, they cannot do effectively without understanding.

Today because of scientific development it is also true that almost anyone is your neighbor. It is indeed an understatement to say that this is a social condition of vast importance. A large percentage of the world is underfed, while there are surpluses of food elsewhere. There is little security. Our prospects for peace and prosperity change with the moon. There is plenty of opportunity for us to get acquainted with the world and its various people if we are able to read, see, and listen, and wish to do so. These are glimpses of our social world. It, too, has been frequently described with great detail in many places.

Again scattered through this Yearbook are words that describe today socially: national emergency, international understanding, integration, automation, insecurity, United Nations, Civil Defense, and many others. The social principles inferred by these words tend to show the kind of social world in which we live. Some people take a dim view of the future of mankind and today's world; others believe we are on the brink of a "bright new world" in which men will learn to live together in harmony, and ever increase their command of the environment for their pleasure, comfort, and needs.

With this brief picture of our social and scientific world in mind, let us examine the experiences we are providing, or should provide, for children who are today building their foundation for living, learning, and thus becoming increasingly effective citizens.

TODAY'S SCHOOL—ITS RESPONSIBILITY—ITS PROBLEMS

It is with reference to such a world as is described in this Yearbook that we must consider the education of children, It is in such a world that they play cowboy and Indian, look at television, ride bicycles, go to Sunday School, read, join the Brownies and Cubs, and go to school.

For years educators have recognized the fact that individuals need not and cannot wait until they are 15 before they begin to learn about the world in which they live. Much thought, time, and energy has gone into deciding what experiences will help children to be, and continue to be, good citizens in today's world, and how children can best become acquainted with the scientific and social aspects of their surroundings. Such considerations are loaded with problems; many still unsolved. A few of the more urgent questions are listed here for consideration as we look at children in relation to the world in which they live today:

How much attention should be given to the natural interests of children? To what extent are we charged to broaden this interest, arouse new interests, and even pursue some problems that appear to take considerable prodding to make them learnable?

How can some of the more abstract, but nonetheless, important ideas, principles, and generalizations of our scientific and social world be made real to children?

What are reasonable goals for children to achieve with respect to interpreting their social and scientific world?

What constitutes worthwhile activities for children to pursue in achieving these worthy goals?

How much can children profit by attempting to grapple with some of the problems which adults themselves have been unable to solve?

To what extent can the scientific and social aspects of the environment be brought together in the minds of the young so that they may be meaningful and useful?

Obviously we cannot hope to deal with all of these fundamental problems with any degree of completeness here, instead we shall briefly inventory the present situation and set forth a point of departure by which the program offerings in science and social studies may become more effective in the elementary school. It is encouraging to believe that in the past 20 years we have made real progress in the direction of solving some of the problems listed. Greater progress has been made with some of the problems than with others. At least the procedures in many schools are past the Indian tepee stage of social studies and have advanced from the leaf-pressing era of science teaching to something more likely to produce the desirable changes in behavior which we believe are important. We have become more conscious of responsibility to our objectives--or is that wishful thinking? We have looked more closely at the needs, interests, and aptitudes of children, discovered more about their growth and development and how they learn, and made some real attempts at designing a curriculum in social studies and in science that takes these factors into account. Lest we become too optimistic in our description of practice, let us say that there are many places where this is true, but there are also many where it is not.

Specifically, we have begun to ask ourselves such searching questions as:

1. To live in a mechanized, diminished-sized, restless, interesting world, what do children need?
2. To be an effective citizen in such a world, what attitudes, appreciations, skills, and knowledges are essential?
3. To contribute to its future development, to right some of its wrongs, to profit from its history and to help in the future to realize its potential, what do its future adults need?

Whatever decisions we reach in answer to such questions constitute the responsibility of the home, the school, and the community for education of today's children.

This leads us to a consideration of the two subject areas in the elementary curriculum that are expected to assume the major responsibility of helping our youngest citizens to become acquainted with the world and its people. They are social studies and science. Together they are expected to accomplish the job of informing, creating attitudes, developing the ability to tackle and solve problems, and do many other things which we shall now attempt to consider.

It seems reasonable to assume that before science and social studies can be considered together they must be examined separately. Unless there exists some understanding of each, it is hardly possible that their overlappings, relationships, mutual contributions, and individual potentialities can be realized. There are many who believe that herein lies one of the fundamental reasons for some of the past and existing failures in fusing the two. They also believe that programs have been constructed purporting to fuse the two areas by curriculum builders who, for one example, are woefully lacking in science background. Consequently, the so-called science included is inappropriate, insufficient, or unnecessary. This point will be discussed more fully later.

THE SOCIAL STUDIES PROGRAM—ITS CONTRIBUTION

Let us first consider the social studies part of the curriculum: the history, civics, geography, citizenship, human relations. These and some other areas have in many cases been lumped together and considered as one large area of the curriculum. What does this area recognize as its share of the burden of educating today's children?

The objectives of the social studies program for the early school experience have been variously stated. For our purposes we cite the following as some of the essential accomplishments intended for children as they proceed through their early years in school. It is hoped that pupils will:

1. Grow in skill in searching for, evaluating, organizing, using, and presenting material essential to solving problems of man's interaction with his environment as he meets his basic needs. That is to say, pupils through experiences designed especially for that purpose, become increasingly capable of using learning tools to solve problems related to man's struggle through the ages to provide food, clothing, shelter, and other basic needs as he lives under various conditions on the earth.
2. Come to possess organized knowledge of the world's past, and have the ability to interpret this knowledge as it relates to the present and possible future
3. Develop an understanding of the meaning of democracy, and of the role which individuals play in a democratic society, this understanding to be increasingly obvious by pupils' actions, attitudes, appreciations, and understandings, and to be learned through living and learning in and out of school
4. Begin to have an understanding of the place of our democracy in the world and of the part that individuals and groups play in such relationships
5. Learn to recognize significant problems, to grow in ability to solve them effectively, and to see the importance of maintaining an open mind and a questioning attitude.

Although these are by no means the total objectives assigned to the social studies program, they are some of the more important, profound, far-reaching, all-inclusive desires which it is hoped will result through our social studies experiences. It is important to note that attaining such objectives does not *automatically result* from having made a relief map of Mexico with the mountains and rivers, participating in an interview with a visiting English woman who answered questions about a British Christmas, or from having built a model of a covered wagon. Attitudes, appreciations, skills of problem solving, and the other elements of the objectives we have stated are not achieved unless teachers intend that they shall be achieved. When teachers intend to achieve objectives, they teach so that they will result. Such teachers must first *believe in the importance* of the objective. Then they must *understand* their meaning and know how to plan and carry out activities with children that make these achievements inevitable. A social studies program that will accomplish these worthy aims must concern itself with the solving of fundamental problems. With such vital tasks to perform it has no time to waste on trivia. There is at present much school time wasted in aimless activity that results in nothing but tired teachers on Friday nights. There are those who believe that the things we are doing throughout our whole school program with children need to be examined more thoroughly in light of their possibilities for accomplishing our objectives.

THE SCIENCE PROGRAM—ITS CONTRIBUTIONS

Science is the other subject-matter area charged with helping elementary school pupils fit into today and live wisely tomorrow. Let us examine briefly what significant contributions it purposes to make to the intellectual equipment of pupils.

First, however, what is meant by science in today's elementary school? By now the teachers should be well past the coloring-robins-and-mounting-leaves stage. Today's science program is chiefly concerned with identifying problems and in solving them. The problems come from such areas as: weather, astronomy, electricity, magnetism, sound, heat, light, plants, animals, and conservation. Science today is concerned chiefly with: (a) planning activities that can be expected to solve these problems; (b) carrying on these activities; (c) organizing the resulting knowledge; (d) applying this knowledge to the problems set up; and (e) evaluating the results. In other words it must relate definitely to the scientific world which we have looked at briefly in the introduction to this chapter.

What results can be hoped for in the elementary school through the study of science? Educators who have devoted much thought, time, and research to this problem believe that after some years of science study pupils should:

> 1. Be more skillful at solving problems effectively than they would have been if they had not studied science. They should be more skillful in stating a problem carefully, suggesting reasonable methods for solving it, selecting the most sensible methods, following them through, and applying the findings.

2. Be more scientific in their attitudes. This means that having had effective problem solving experiences, pupils will become more cautious about drawing conclusions, more likely to challenge sources of information, more thorough in observation, less likely to generalize from too little or inappropriate information, and less inclined to be superstitious. Through experimenting, observing, asking, reading, and other learning activities in science, such elements of a scientific attitude as these are expected to develop.

3. Be more appreciative of their physical and natural environment and be more interested in it. For example, having learned what makes it rain, how chemical changes take place, how airplanes fly, and bees live together, pupils are expected to have developed an appreciation for the wonderfulness of the world in which they live, and have a feeling of wanting to know more and more about this world as they continue to live in it.

4. Possess useful, organized knowledge to interpret their world of forces, changes, energies, living things, and phenomena. This does not mean that pupils will have only a collection of unrelated facts about how hot the sun is, how cold liquid air is, how fast sound travels, and how many legs spiders have. It means that pupils have developed understandings. For example, understanding that heating causes most kinds of matter to expand, cooling causes them to contract, is an accumulation of related facts that, when put together, constitutes a scientific principle. It can be used to understand such things as why screw tops of glass jars come off if you run hot water over them, why bridges sometimes buckle in hot weather, and why pavements are sometimes bumpy on hot days.

In addition to these results and as an outgrowth of them, it is hoped that some new Pasteurs and Einsteins will develop because of satisfying elementary school experience with science. And in these days of shortage in scientific manpower this is especially important. Who knows how many potential scientists have never developed because of lack of opportunity to begin at an early age? It is certainly important that interest and talent be identified and encouraged whenever it appears and experience indicates that this often occurs in early years of school.

Here again, as in the case of the social studies, the objectives are not attained automatically by pupils through having lived in the same room two or three hours a week with a science teacher, read a series of science books, and filled in the blanks of a workbook. The results we have listed come about only if pupils are fortunate enough to be in a school where teachers *understand* these objectives, and realize that they must intend to achieve them whenever they work with children. Indeed and unfortunately it is possible to go through eight or nine years of science and hardly brush up against a scientific attitude or employ a sound technique for solving a problem. That it is possible to do so is repeatedly demonstrated.

Social Studies and Science

Since these two areas—science and social studies—are charged with such important missions to accomplish, it seems to some educators that they must be fundamentally related and should be fused or pursued together as one block of learning. This point of view has undergone change in one direction or another as have our deliberations about other curriculum and teaching problems when we test them. The amount of fusion of science and social studies advocated by various educators runs the whole gamut from: "We teach *all* of our science and social studies together," to "Our science and social studies programs are entirely separate." Every year that passes finds fewer persons lined up with either of these extreme schools of thought, for reasons which will be considered presently. Probably the more successful programs, from the standpoint of the results accomplished by children, are those that subscribe to a point of view somewhere between these extremes; that is, there are times when the two programs fuse, times when they relate temporarily, and times when they operate independently of each other. Let us further explore these ideas.

What procedures are used to decide to fuse or not to fuse? The first step is taken when the program objectives for both fields are defined, set down in understandable language, and seriously contemplated. Having decided how one wishes children to change as a result of having studied science and social studies, the next question is: What important problems will constitute the subject matter of the two areas? In other words, what are, as far as can be told, the essential *subject-matter meanings* to be gained which are peculiar to each subject area? What *knowledge* do we feel is important to children in order that they may make progress in the direction of attaining the objectives? Having identified the problems and thus the program content, the next question is: What will the learners do in order to solve these problems and attain the objectives? The answer to this question constitutes the learning activities which make up the program. The big, significant problems, the subject-matter content, have now been identified and the activities selected.

But how does this help to decide whether to fuse or not to fuse the two programs? Suppose for each of the major problems that make up the science or the social studies curriculum one asks:

What subject matter is essential to solving these important problems? Does the subject matter needed come primarily from the field of science, or primarily from the field of social studies, or does it come from both?

It is here that a knowledge of both fields is important and as has been stated previously, there are those who are inclined to wonder if some of the present program where fusion is the watchword may have been constructed by educators who are acquainted with only one field, namely, social studies. This situation may be the result of many different causes which will not be considered here, but without knowledge of science it is hardly possible to see its potentialities and relationships. The same is, of course, true for social studies.

Look now at examples of problems that will serve to illustrate the degrees of fusion or nonfusion just indicated. One problem generally considered by most educators as having real value in the elementary school is: What are the problems of conservation in our state and what is being done to solve them? Why does this problem seem sensible for 11- or 12-year-olds? Look again at the over-all objectives cited earlier and see what a study of this problem can contribute toward achieving them. Through the activities involved in solving the problem it is hoped that pupils will:

1. Come to understand that there are many important problems of soil, water, wildlife, mineral, and plant conservation in the state
2. Realize that these problems must be solved by the people of the state today, and tomorrow, and tomorrow
3. Develop an attitude of urgency toward these problems and realize that solving them is everyone's business and responsibility
4. Learn something about how to tackle a problem, solve it, organize the findings, and share them with others
5. Learn how a state government operates to solves these problems
6. Understand the science principles underlying these problems and see how these understandings are used in solving the problems.

Even when giving close attention to these objectives it is difficult to tell which ones are social objectives; which, scientific. They are interlaced. They are all important in bringing about desirable changes in the minds of the learners. In order to achieve these objectives, both science and social studies content is essential, so one might say, "What difference does it make whether we label it science or social studies?" Also, and this seems important to many educators, both the science and social studies subject matter is *sensible for* this age level (11- or 12-year-olds). There is enough of both types of subject matter to provide formation of social and scientific principles which can be understood and if taught successfully will influence behavior. There is enough subject matter in both areas to make good organization possible; enough to produce important principles and not just a collection of random facts. To be specific: in the science field, pupils will learn what soil is, how it is formed, and how it relates to other resources. At the same time from the social point of view, pupils will come to see the importance of conservation regulations, who makes such laws, why it is important that everyone observe them, and what will happen if they are not taken seriously. They begin to connect the past conservation procedures with the present and both with the future.

Here, then, is an example where the objectives set up for the study of a major problem cannot be realized without both science and social studies material. The two areas need each other. They are jointly beneficial. Considering them together helps pupils to gain knowledge, attitudes, skills, and appreciations considered important to them. The relationship is obvious. There are other examples of problems where the two areas mesh and separation is obviously undesirable. Some of these are: How can living conditions in our community be improved? How have scientific inventions influenced the way we live?

However, the examples where complete fusion is desirable are relatively few considering the whole elementary school program. On the other hand, there are many other problems where the relationship is much less obvious and compelling. As an example, consider another problem that is a part of many courses of study in social studies: What important discoveries did explorers make in the early history of the New World? What do we hope to accomplish through the solving of this problem in Grades V or VI? Some of the following:

1. An appreciation for the accomplishments of early explorers and of the importance of their discoveries
2. Some knowledge of the geography of the country
3. Some understanding of the historical aspects of the development of our country
4. Increased ability to find, organize, and present material in a problem solving situation.

Looking at these objectives it seems fairly obvious that they are chiefly social studies objectives. They are specific objectives that contribute to the general social studies objectives cited earlier. The problem itself is primarily social studies. *But* in our zeal to fuse we decide that there must be some science implications involved here and decide to teach, to cite two common examples, about compasses and telling directions by the stars. The latter is often maneuvered by the teacher into a more or less haphazard experience with astronomy. The compass is explained in five minutes. This procedure in itself would not constitute a crime but unfortunately procedures like it make up the total science program of a great number of children living in what we glibly describe as the age of science. Furthermore, an extensive study of stars and compasses is not essential to the achievement of the objectives we have set up. In solving the problem we are only concerned with the one use of the compass and the North Star or other star groups. A protracted study of either of them may indeed lead us afield and we can easily lose the thread leading to achieving our objectives for the study of early explorers. It would seem more sensible to discuss briefly the part compasses and stars played and go on with the explorers. We dip only briefly into the field of science and leave the detailed study of astronomy and compass for a later time when they can form part of a problem where their science aspects can have real meaning.

Another point to consider is the fact that in order to understand the compass as a scientific instrument, a study of magnets, the earth as a magnet, and the general nature of magnetism is essential. Compasses are in wide use in today's world and the use of the force of magnetism has completely revolutionized our way of living today. This would in itself seem adequate reason for an organized study of magnetism and the compass without tying it with so timid a string to the early explorers. When such a science study as this is going on it would make good sense to help pupils recall their experience with explorers and in so doing see more clearly the relationships. This demonstrates that there can be some degree of fusion even though the two areas are not being considered at the same time. Relationships of the two areas may often be pointed out to children as the areas are studied. In many cases such treatment is all the fusion needed.

Stars, the moon, planets, eclipses, rockets-into-space, the man-made-earth satellite are within the everyday experience of today's children. Problems related to astronomy today and in the future are of real interest and concern to today's children. Anyone who lives with today's children knows their zeal for knowledge of astronomy. How important is it then that such vital concerns be tied to early explorers? It is possible that tying them together may destroy the interest in both by distorting the focus of each? It is such questions as this that curriculum makers need to consider in deciding whether or not fusion of the social studies and science is desirable.

Scientific principles are understood only through organized study consisting of observing, experimenting, reading, and other activities. Dipping here and there into the sciences as they are needed for social studies understanding cannot possibly result in comprehension of any of the essential scientific understanding. Such random sampling does not constitute a satisfying science course for today's children. The same is true of the principles of social living. They too need organized consideration if they are to be functional. They cannot be successfully understood if their presentation is not carefully planned. Flights into the field of science when the resulting study is nonessential to the development of a social concept may indeed hinder the social studies program. Both the social studies and science subject matter must be so carefully organized that they will have definite direction, structure, and sequence. The subject matter of both areas must be organized in terms of significant problems, the answers to which will make a difference to the learners and not result merely in the acquisition of scattered fact soon forgotten because of their insignificance. As has been pointed out before, such a planned program may still permit individual teachers to use originality. It is the relationship of science and social studies that is often transient and incidental.

The examples of inept attempts at fusing the two disciplines are legion. Making soap during the study of pioneers is a good example. Soapmaking in itself may be justifiable since it acquaints pupils with a process, but the science involved in soapmaking is inappropriate for elementary school. The chemistry of soapmaking is a complicated process. One supervisor expressed the situation well when she said, "We do things like soapmaking but we don't call it our science. We think our science experiences should be at the level of experience and comprehension of the pupils."

Perhaps we are overlooking one of the important aspects of fusing these two areas of the elementary school. It is usual for us to begin to think of integrating two areas by considering the subject matter of the two areas. But let us re-examine our objectives. Understanding of the subject matter in both areas is but *one* of the objectives. Indeed, we frequently explain the field of science as having two major aspects: one a method of discovery, the other an organized body of knowledge. The development of scientific attitudes and growth in problem solving are major intentions in science. Similar objectives are also held for the social studies: the ability to solve problems and the development of attitudes toward peoples and cultures. Perhaps here is the place where fusion in the two areas should be emphasized more than it now is, provided, that is, that the instruction in both areas is really designed to accomplish the objectives. The scientific method of problem solving—the way in which knowledge grows in science—is the same as in the social studies. The scientific method of problem solving is a universal method. In both science and social studies we identify problems, state them carefully, decide on procedures for finding the answers, follow these procedures, and apply our findings to answering the problems.

The scientific method of problem solving cannot be effective if a scientific attitude has not been used by the problem solver. Essential elements of a scientific attitude to good problem solving in science might be summarized for pupils in a few brief sentences:

Don't jump to conclusions.
Look at a matter from every side.
Go to reliable sources for your information.
Who says it is as important as *what* they say.

Be willing to change your mind in the face of newer, more reliable evidence.

These principles are equally as important in solving problems in the social studies, consequently fusion *of the method of discovery* in the two areas makes real sense to many educators. They are content to fuse the methods of discovery and in many cases let the subject matter develop in its own separate ways, especially when they have no need for each other in achieving the objectives. Fusion of subject-matter areas in many cases seems to them to be unimportant, often unnecessary, frequently even destroying the attainment of objectives for both fields.

In both science and social studies there is great need for a careful examination of present practices. Neither field can contribute its important share toward achieving its objectives unless the program is carefully designed. Neither chance happenings nor the sudden spurts of enthusiasm of one or two individual children for a certain topic can constitute the reason for selecting the content, though "teachable moments" and interests of children should not by any means be ignored. Science and social principles become a part of pupils' intellectual equipment only as a result of a well-planned program.

In the field of social studies educators have produced a more logical and definite sequence of problems for study than they have in science. Long ago they realized that a course of study cannot be built on chance. Hardly anyone believes that we should wait to study Community Helpers until a fire breaks out in the community and the fire department springs to action. We have sound reasons for assigning the problems related to community helpers to certain grades in the elementary school. But some educators still believe that a good science program can be built on eclipses, dead birds and the insects children drag to school, or questions they ask about rockets. Such procedure results in a hodgepodge of science and distraught teachers.

Nor can the content, method, and sequence of development in either science and social studies be left to the discretion of individual teachers, especially since many of them are inexperienced in science. All teachers have reasons to expect intelligent guidance in these matters. Granted they should be urged to help in the selection of content, method, and organization, the fact still remains that no really effective program can result without over-all planning for the entire school system covering all grades.

Pupils today deserve to spend their time in science and social studies solving problems that are important. The activities must be chosen because of their contributions to solving the problems and consequently because of their relationship to the objectives. Greater attention to these two considerations will help in a large measure to eliminate a considerable amount of the nonsense that exists at present in both the science and the social studies program. Any piece of the curriculum that assumes the responsibility related to these two areas must indeed be examined and re-examined if it is to stay abreast of new achievements. It cannot afford to be out of date. It cannot afford to leave out fundamental concepts because children do not happen to bring them up. It cannot afford to skip whole areas of science problems because they do not happen to fit into the existing social studies pattern, nor can it be complete if the social studies concepts are only those that tie into the science.

CHAPTER XI

The Interrelations of Science and Social Studies at the Secondary Level

Ellsworth S. Obourn

The future of every young person in America will be inevitably conditioned by environmental problems created by the discovery and application of new scientific knowledge. The past half century has witnessed changes which have moved us from the tempo of the horse and buggy to rockets and guided missiles which travel at supersonic speeds; from the telegraph to wireless, radio and television; from the low energy level of burning coal to the mega ton energy of atomic fission and fusion. Each of these and many other technological advances have brought attendant social perplexities as consequences and have created foci of individual and group problems which must be met and solved. There is every reason to infer that the future will bring an acceleration in the discovery of new knowledge and an increase in the number and complexity of problems in the lives of people.

Interrelations of Social Studies and Science

Writers in both of these areas have long pointed out the close relationship of science to social studies. In fact it has become an accepted axiom that, for the purposes of education, these areas are so inextricably bound, as to form, in many cases, a cause and effect relation. However, in only a few cases have these writers indicated the true nature of the pattern.

On first analysis one is prone to believe that technological change is inevitably the causal factor and that the attendant social consequences follow as effects and indeed this is frequently true. But, while science and technology have exerted a great influence on society over the past three centuries, it must be noted that in the last half century, society has played an increasing role in the shaping and molding of science. The constant interplay between social phenomena and technology presents a strong case for the closer integration of the two areas at the secondary level, not alone for the purposes of general education, but equally for education that will lead to specialization in either area. It is difficult to find topics for study in any area of the social sciences which do not relate, in one way or another, to some concept of science. By the same token it is equally as hard to find topics in science which, either in their antecedents or consequences are not illuminated by social interplay. One example will make clear the close interrelations of the basic concepts of social studies and science.

THE ENERGY CONCEPT

Civilization as we know it today is made possible only because we have an abundant supply of energy. The energy concept is the basic theme which unifies all of science. Any topic or problem studied at any level in the science curriculum must be considered as an outcrop of the underlying energy theme.

In social science many topics that are commonly studied have their origin in the energy concept, among these can be mentioned the Industrial Revolution, transportation, communication, the distribution of population, the food supply, and the conservation of natural resources. The problem of nuclear energy ramifies into many areas of the social studies especially into such topics as war and peace and the future use of the atom as a source of power. The implications of atomic energy for social studies is summarized as follows in a pamphlet of the National Association of Secondary-School Principals:

> . . . What might the new world be like? What kind of a world will you and your friends live to see materialize? Many predictions have been made since Hiroshima about the atomic age, the new world a-coming. Most of these predictions are possible but only if a variety of problems—scientific, engineering, economic, political—are solved. In brief, this new world might develop into something like this. Energy will be cheap and plentiful. An endless stream of consumer goods will flow from automatic factories. You may live to drive a plastic car powered by an atomic engine and reside in a completely air-conditioned plastic house. Food will be cheap and abundant everywhere in the world. It is unlikely that you or any of your classmates will die prematurely of cancer or heart disease or from any contagious diseases or from any of the other human ills that afflict us now. Many of your generation will reach the century mark but this will bring them little publicity. No one will need to work long hours. There will be much leisure, and a network of large recreational areas will cover the country, if not the world. The new world, if it develops, will be so interdependant that war and international strife will be impossible. Human relations will reach new heights and matters of spirit will assume new and greater significance.[1]

Similar illustrations from the areas of health, conservation, consumer education, safety and others might be used to further illustrate the ways in which the basic concepts from science and social studies interplay.

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[1] National Association of Secondary-School Principals. *Operation Atomic Vision.* Washington, D.C.: the Association, a department of the National Education Association, 1948. (Out of print.)

Developing understanding for the basic concepts of science and social studies is a means to the end of better adjustment on the part of individuals about the many problems which arise in their day to day living patterns. If one were to determine specifically the basic needs of people in solving personal and social problems, it would be essential to analyze all of the life activities in which these problems would be confronted. Since the realm of life activities is so general and varied it would be impossible to analyze them as such. Thus it is more feasible to classify them into a more comprehensive scheme such as the following:

1. Adjustments of a self-personal nature
2. Adjustments to home and family life
3. Adjustments to community perplexities
4. Adjustments to economic relationships.

In each of these basic areas of adjustment the scientific and social concepts are so intimately related as to be almost inseparable. At many foci in these areas problems arise, both for young people and adults, which must be solved if they are to live fully. Thus it seems reasonable to assume that science and social studies in the secondary school curriculum should seek to do more than to provide mastery and understanding for the basic concepts. To be effective, these subjects must be taught in such a way that the students will develop the attitudes and skills of problem solving to such a degree as to enable them to cope successfully with the new problems which will confront them in this age of technology.

Equipping young people with understanding of the scientific and social concepts involved in the areas of adjustment listed above, together with the attendant skills of problem solving, are among the broad purposes for education in the secondary school. The following summary of each of the areas of adjustment will indicate in a general way some of the social and scientific understandings that should be developed in each one. Later, the problem-solving objective will be discussed in detail.

ADJUSTMENTS OF A SELF-PERSONAL NATURE

This adjustment area will be concerned with such aspects of the individual as the physical, mental and emotional. In making a successful adjustment to himself it is essential that the individual understand his mental and physical make-up and how his biological development is conditioned by certain hereditary and environmental factors. He must have an understandng of the concepts of: personal health; proper sex adjustment; the biological basis of emotional development; and concepts basic to seeing his own life pattern as a part of the general life pattern we must live as human beings in human association.

Adjustments to Home and Family

This area will include the adjustments the individual will make to those with whom he has the closest association. Such associations are usually identified in the home and the immediate small social groups into which he is thrown. It is necessary that he have an understanding of those factors that determine behavior in social groups, of the development of standards by means of which society involves the individual, and of those factors of the physiological development of boys and girls that condition their behavior. In order to properly make these adjustments the individual must have an understanding of the place of the child in the home; the desirable relationships of child to parent; the selection of a mate; courtship; marriage; childbearing; and maintenance of a home.

Adjustments to the Community

In this area are to be found the adjustments which all individuals make to local civic enterprises and to governmental agencies and institutions. There are a great many services offered by the community, conditions existing in the community, and movements undertaken by the community which have socio-scientific aspects, and concerning which an individual living in the community may have problems. Among these would be the water supply, the swimming pool, civil defense, sewage disposal, health agencies, living conditions, public safety, and other problems of community concern.

Adjustments to Economic Relationships

This area will include the large number of adjustments which the individual must make to situations concerned with the matter of making a living, and buying and selling various commodities, and services. In this area he must have an understanding of the need for the conservation of natural resources, the selection and purchase of commodities essential to life, uses of machines, public utility services, communication, transportation, the development of new processes and materials, the sources and utilization of energy, and the selection of a vocation. It is probably true that the conceptual understandings in this area of adjustment will most likely be emphasized from the point of view of the consumer rather than from that of the producer.

The Method of Science

There have been many attempts to make a clear definition of the method of science, beginning with Francis Bacon's *Novum Organum* and Descartes' *Methode,* and continuing on down through such early writers as Locke, Kant, Whewell, Mill and Lotz to the more recent works of Dewey, Poincare, Mach, Duhem and others. These form indeed, an illustrious group worthwhile to the scholar but not of much use to the busy teacher of science or social studies eager to keep pace with the rapid progress of his field.

Most of the outlines or formulas that have been produced to suggest the method of science leave much to be desired from the standpoint of the teacher. In the first place these analyses omit one factor which appears to be basic to the use of the method by scientists. This is an element of wonder or emotion, a deep stirring that gives to the investigator an insight to a discrepancy in some existing state of affairs. It is this sensing of discrepancy and the emotional urge to find new and unknown evidence to bridge over the gap, which truly distinguishes the genius from the ordinary mortal.

Galileo in his famous experiments on falling bodies most certainly made use of the method of science. But what was it that led him to undertake the investigation? Many before him, even as remote as Aristotle, had observed the phenomenon and had recorded certain dogmas about it. It was perhaps a sensing of discrepancy between these recorded statements and the facts which urged Galileo to his epoch-making studies. Thus, for purposes of education, the mind-sets, or attitudes involved must not be divorced from the method of science if its mastery is to be complete and its use in new situations really effective.

In the second place the outlines of critical or reflective thinking leave much of detail to be desired. They are only outlines in the strictest sense and leave much to be filled in by the teacher who desires to guide his pupils into an understanding of, and an ability to use the method.

Problem Solving Is Basic to All Education

The method under discussion has been characterized as the scientific method, the method of reflective thinking, the method of critical thinking and in other ways. There appears to be a growing disposition on the part of those concerned with the education of young people to speak of this objective as the problem-solving method.

The development of an orderly procedure for solving problems is not peculiar to any particular subject. It has been recognized as an objective by many courses offered in the high school curriculum. The important consideration is that the objective has not been attained to its fullest potentialities. This condition results from the failure on the part of teachers to realize that it must be taught just as vigorously as we now teach for the mastery of facts and principles.

Learning situations must be provided which will give the pupil an opportunity to practice the skills of problem solving, day after day in the classroom. Only then can we hope for some evidence that the objective is being achieved.

ACHIEVING THE PROBLEM-SOLVING OBJECTIVE

Before any objective can become a guide to the selection of materials of instruction as well as methods of instruction, it must be analyzed into its elements. The following outline provides an analysis of the problem-solving objective in terms of the behavior changes which must be brought about in young people if the objective is to be realized to the extent that it becomes operative in their daily lives.

PROBLEM-SOLVING BEHAVIORS[2]

I. Attitudes which can be developed through teaching

The program in the secondary school should develop the attitude which will modify the individual's behavior so that he:

- A. Looks for the natural cause of things that happen
    - 1. Does not believe in superstitions such as charms or signs of good or bad luck
    - 2. Believes that occurrences which seem strange and mysterious can always be explained finally by natural cause
    - 3. Believes that there is necessarily no connection between two events just because they occur at the same time
- B. Is openminded toward work, opinions of others, and information related to his problem
    - 1. Believes that truth never changes, but that his ideas of what is true may change as he gains better understanding of the truth
    - 2. Bases his ideas upon the best evidence and not upon tradition alone
    - 3. Revises his opinions and conclusions in light of additional reliable information
    - 4. Listens to, observes, or reads evidence supporting ideas contrary to his personal opinions
    - 5. Accepts no conclusion as final or ultimate
- C. Bases opinions and conclusions on adequate evidence
    - 1. Is slow to accept as facts any that are not supported by convincing proof

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[2] This analysis was prepared by Dr. Darrell Barnard, Professor of Education and Head of the Department of Science Education, New York University, and Dr. Ellsworth Obourn, U. S. Office of Education.

    2. Bases his conclusions upon evidence obtained from a variety of dependable sources
    3. Hunts for the most satisfactory explanation of observed phenomena that the evidence permits
    4. Sticks to the facts and refrains from exaggeration
    5. Does not permit his personal pride, bias, prejudice or ambition to pervert the truth
    6. Does not make snap judgments or jump to conclusions
  D. Evaluates techniques and procedures used, and information obtained
    1. Uses a planned procedure in solving his problems
    2. Uses the various techniques and procedures which may be applied in obtaining information
    3. Adapts the various techniques and procedures to the problem at hand
    4. Personally considers the information obtained and decides whether it relates to the problem
    5. Judges whether the information is sound, sensible, and complete enough to allow a conclusion to be made
    6. Selects the most recent, authoritative, and accurate information related to the problem
  E. Is curious concerning the things he observes
    1. Wants to know the "whys," "whats," and "hows" of observed phenomena
    2. Is not satisfied with vague answers to his questions

II. Problem-solving abilities which can be developed through teaching

The program in the secondary school should develop those abilities involved in problem solving which will modify the individual's behavior so that he:

  A. Formulates significant problems
    1. Senses situations involving personal and social problems
    2. Recognizes specific problems in these situations
    3. Isolates the single major idea in the problem
    4. States the problem in question form
    5. States the problem in definite and concise language
  B. Analyzes problems
    1. Picks out the key words of a problem statement
    2. Defines key words as a means of getting a better understanding of the problem
  C. Obtains information regarding a problem from a variety of sources
    1. Recalls past experiences which bear upon his problem
    2. Isolates elements common in experience and problem
    3. Locates source materials
      a. Uses the various parts of a book
        (1) Uses key words in the problem statement for locating material in the index
        (2) Chooses proper subtopics in the index
        (3) Uses alphabetized materials, cross references, the table of contents, the title page, the glossary, figures, pictures and diagrams, footnotes, topical headings, running headings,

marginal headings, an appendix, a pronunciation list, and "see also" references
  - b. Uses materials other than textbooks such as: encyclopedias, popularly written books, handbooks, dictionaries, magazines, newspapers, pamphlets, catalogs, bulletins, films, apparatus, guide letters, numbers, signs, marks in locating information, bibliographies
  - c. Uses library facilities such as: the card index, the *Readers' Guide to Periodical Literature,* and the services of the librarian

4. Uses source materials
    - a. Uses aids in comprehending material read
        - (1) Finds main ideas in a paragraph
        - (2) Uses reading signals
        - (3) Formulates statements from reading
        - (4) Phrases topics from sentences
        - (5) Skims for main ideas
        - (6) Learns meanings of words and phrases from context
        - (7) Selects the printed material related to the problem
        - (8) Cross-checks a book concerning the same topic
        - (9) Recognizes both objective and opinionated evidence
        - (10) Determines the main topic over several paragraphs
        - (11) Takes notes
        - (12) Arranges ideas in an organized manner
        - (13) Makes outlines
    - b. Interprets graphic material
        - (1) Obtains information from different kinds of graphic material
        - (2) Reads titles, column headings, legends and data recorded
        - (3) Evaluates conclusions based upon the data recorded
        - (4) Formulates the main ideas presented
5. Uses experimental procedures appropriate to the problem
    - a. Devises experiments suitable to the solution of the problem
        - (1) Selects the main factor in the experiment
        - (2) Allows only one variable
        - (3) Sets up a control for the experimental factor
    - b. Carries out the details of the experiment
        - (1) Identifies effects and determines causes
        - (2) Tests the effects of the experimental factor under varying conditions
        - (3) Performs the experiment for a sufficient length of time
        - (4) Accurately determines and records quantitative and qualitative data
        - (5) Develops a logical organization of recorded data
        - (6) Generalizes upon the basis of organized data
    - c. Manipulates the laboratory equipment needed in solving the problem
        - (1) Selects kinds of equipment or materials that will aid in solving the problem
        - (2) Manipulates equipment or material with an understanding of its function to the outcome of the experiment

        - (3) Recognizes that equipment is only a means to the end-results
        - (4) Determines the relationship between observed actions or occurrences and the problem
        - (5) Appraises scales and divisions of scales on measuring devices
        - (6) Obtains correct values from measuring devices
        - (7) Recognizes capacities or limitations of equipment
        - (8) Returns equipment clean and in good condition
        - (9) Avoids hazards and consequent personal accidents
        - (10) Practices neatness and orderliness
        - (11) Avoids waste in the use of materials
        - (12) Exercises reasonable care of fragile or perishable equipment
    - 6. Solves mathematical problems necessary in obtaining pertinent data
        - a. Picks out the elements in a mathematical problem that can be used in its solution
        - b. Sees relationships between these elements
        - c. Uses essential formulae
        - d. Performs fundamental operations as addition, subtraction, multiplication and division
        - e. Uses the metric and English systems of measurement
        - f. Understands the mathematical terms used in these problems; i.e., square, proportion, area, volume, etc.
    - 7. Makes observations suitable for solving the problem
        - a. Observes demonstrations
            - (1) Devises suitable demonstrations
            - (2) Selects materials and equipment needed in the demonstration
            - (3) Identifies the important ideas demonstrated
        - b. Picks out the important ideas presented by pictures, slides, and motion pictures
        - c. Picks out the important ideas presented by models and exhibits
        - d. Uses the resources of the community for purposes of obtaining information pertinent to the problem
            - (1) Locates conditions or situations in the community to observe
            - (2) Picks out the essential ideas from such observation
    - 8. Uses talks and interviews as sources of information
        - a. Selects individuals who can contribute to the solution of the problem
        - b. Makes suitable plans for the talk or interview
        - c. Appropriately contacts the person who is to talk
        - d. Selects the main ideas from the activity
        - e. Properly acknowledges the courtesy of the individual interviewed
- D. Organizes the data obtained
    - 1. Uses appropriate means for organizing data
        - a. Constructs tables
        - b. Constructs graphs
        - c. Prepares summaries
        - d. Makes outlines

        e. Constructs diagrams
        f. Uses photographs
        g. Uses suitable statistical procedures
- E. Interprets organized data
    1. Selects the important ideas related to the problem
    2. Identifies the different relationships which may exist between the important ideas
    3. States these relationships as generalizations which may serve as hypotheses
- F. Tests the hypotheses
    1. Checks proposed conclusion with authority
    2. Devises experimental procedures suitable for testing the hypotheses
    3. Rechecks data for errors in interpretation
    4. Applies hypothesis to the problem to determine its adequacy
- G. Formulates a conclusion
    1. Accepts the most tenable of the tested hypotheses
    2. Uses this hypothesis as a basis for generalizing in terms of similar problem situations.

A close examination of the problem-solving behaviors outlined above will reveal many opportunities which the teacher of social studies has for providing learning experiences both inside and outside the classroom, that will aid in making these attitudes and skills functional in the lives of young people. Teachers should realize that it is not essential for the complete cycle to be operative on any single problem. It is quite possible that on a given day in a social studies class the learning experiences planned would lend themselves to practicing the ability to define a problem. Another day should be spent in the analysis and interpretation of data, and on yet another day to the recognition of assumptions, or the proposing of hypotheses. Each lesson should be utilized to its fullest potentiality for giving practice to that element of problem-solving behavior for which it is best suited.

Implementing Problem Solving in Social Studies

The Conservation of Natural and Human Resources is a learning topic which cuts across several of the conventional subject matter areas of the secondary school curriculum. It is a topic that may well be considered in social studies, biology, physics, general science, and English. It serves very well to illustrate how problem solving may be utilized in a developmental procedure.

In the study of this topic, many basic concepts, both of science and social studies, will provide the content vehicles through which the desired behavior changes or adjustment patterns can be achieved in the pupils.

Class discussion will lead to the definition of certain specific problems which are of interest and significance to the class. Among these problems might be:

1. Should I support the TVA?
2. Are young car drivers accident prone?
3. Is the fluoridation of a water supply dangerous?
4. Should the testing of nuclear weapons be prohibited by law?
5. Will atomic and solar energy make us independent of fossil fuels?
6. Is it wise for the federal government to build dams on our rivers?

In refining the statement of such problems, the teacher has an opportunity to point up the meaning of key words and to show how these words may lead to source materials in the solution of the problems. Some of the problems will be crucial issues and the discussion of the pros and cons will provide an opportunity for the class to suggest the hypotheses which must be proposed in order that a solution be forthcoming.

The problem and the hypotheses will be predicated on certain assumptions which must be identified and stated. Here the teacher has an excellent opportunity to drive home the differences between fact and assumption and to show how one may be distinguished from the other.

In solving problems like these, pupils will be required to do extensive reading and to recall information gained with previous problems. Much of this reading will deal with writings with varying degrees of objectivity. They will have to read and evaluate advertisements and newspaper reports. These various activities will enable the teacher to teach the pupils how to recognize and distinguish propaganda from real evidence.

The teacher who can give his class an insight into the meaning of true evidence has made their intellectual lives safer and richer. If he attempts to present the abstract principle, his chances of achieving the goal is limited. He can achieve understanding only by placing before the class one concrete illustration after another; thus gradually bringing out the difference between empty "thinking" and real proof.

Writings on the problems of conservation suggested in the foregoing paragraphs abound in opportunities to develop the skills of propaganda analysis and bring out in bold relief the nature of proved evidence. Let us take the problem of the prohibition of the testing of nuclear weapons as an example.

The reports on this timely topic in both newspaper and magazine sources vary greatly in their account of the limiting dosage of radiation from fall-out that is generally safe for human beings. This topic looms large in the present security and perhaps the future survival of young people now in the secondary school depends upon their need to have valid and objective information as well as a correct attitude toward this crucial problem.

Unless situations are provided in the classroom to react to such current problems, it is doubtful if young people will ever develop the attendant skills and habits basic to the evaluation of evidence and the formation of desirable attitudes for the solving of future problems.

In the consideration of a problem on the effects of fluoridating the water supply of a certain locality, an opportunity would be presented where scientific evidence in the form of statistics might be used. These data would again bring up the problem of what scientists mean by experimental evidence and the steps essential to the validation of this evidence. The skills basic to the interpretation of data could be presented and then applied in the evidence under consideration.

Again this might lead into a consideration of the various ways in which a given hypotheses on the effects of fluoridation could be tested.

In the consideration of the problem "Will Atomic and Solar Energy Make Us Independent of Fossil Fuels?" the pupils might be led to the point where tentative conclusions would be reached from the testing of hypotheses and the interpretation of evidence. However, before a final generalization could be accepted, it would be necessary to identify and evaluate the assumptions basic to the acceptance of one conclusion or another. Here again the teacher would have an excellent opportunity to point up the differences between hypothesis and assumption and the basic role which assumptions play in the drawing of conclusions.

Many other problems commonly considered in the social studies courses in the secondary school will offer opportunities for the alert teacher to provide learning situations in and out of the classroom for identifying and using the elements of the problem-solving objective. Only as these are used from day to day in the solution of problems that are real and vital to the pupil can the behavior changes desired be achieved to the degree that they will become a part of their habit patterns and thus be used in day to day living.

CHAPTER XII

Teacher Education

MANSON JENNINGS

THREE conversations were overheard recently in a smoke-filled room —a teachers' room:

A SOCIAL STUDIES TEACHER: Now that I've been teaching for a couple of years I can usually bluff my way out of embarrassing situations, but I sure got caught this morning. In my 11th grade American history class we were discussing the dropping of the first atomic bomb, and to underscore the difference between old-fashioned TNT bombs and the atomic-type bomb I pointed out that the new bombs were developed from Einstein's revolutionary formula, $E = mc^2$. I figured that to have a social studies teacher throw a mathematical formula at them would really make an impression. It made an impression, all right, because no sooner had I brashly displayed my erudition than one of my students wanted to know what the formula meant. At that point I wished I had kept my mouth shut, but doing some quick thinking, I cut off discussion with, "Well, that shows how powerful an atomic bomb is."

ANOTHER SOCIAL STUDIES TEACHER: Yes, I know what you mean. You can get into all kinds of trouble if you let science enter your class discussions. Take the other day in my seventh-period problems course. Someone brought up the subject of automation and asked me what it meant. I supposed it meant an assembly line without any workers—all automatic; but I wasn't sure. So I did the obvious thing and asked the class what they thought it meant. First thing you know I'm trying to maintain an orderly discussion while the students start arguing about whether automation means "continuous-flow production," or "automatic handling of all materials," or "application of the feedback principle." And then some wise guy butts in with the opinion that automation involves the use of electrical brains. That gave me my cue; it seemed reasonably safe to take the position that no one has yet invented a thinking machine like the human brain. So with that statement we got off the subject of automation.

A THIRD SOCIAL STUDIES TEACHER: You fellows are doing it the hard way. Me, I figure all that science stuff is for science classes. I don't try to answer their questions or let them get us off the track into subjects that aren't properly within the scope of the social sciences. I tell my students they can learn what they want about science, but don't bother me about it. In the social studies, all we're interested in is social implications. We don't have to know anything about automation or atomic energy or any of the other scientific innovations of our age. Let the scientists and engineers tell us what their products or processes will do, then we can worry about their social implications.

Undoubtedly many social studies teachers sympathize with the views of these teachers—though we may feel that their pedagogical techniques leave something to be desired. The subject matter of science is well removed from the history, political science, economics, and sociology many teachers studied when they were in school and college. In college they may have had to take a basic course in natural science, but they didn't like it and probably considered it a necessary evil. Yes, they are avid readers but they rarely spend time on subjects unrelated to their field. Books and articles on science and technology in their opinion are for the specialists in those fields. Even if they did happen to be interested in an occasional title in the field of science, they would find it far too technical.

The mere fact, however, that the National Council for the Social Studies is publishing a yearbook on science in relation to the social sciences indicates that perhaps teachers should not be overly complacent about the present treatment of science in social education. So far there has been no coordinated attack upon the problem, but there is evidence that while many are concerned about it, they are not certain where their thinking will take them, but they are hopeful that their efforts will stimulate further thinking and discussion. This Yearbook represents an effort to provoke profitable thinking and discussion.

SCIENCE, TECHNOLOGY AND HISTORY

A century ago historical writing concerned itself primarily with politics, diplomacy, and war. These were believed to be the things that made the world what it was. James Harvey Robinson's "new" history introduced the idea that an understanding of the world would be incomplete without considering also the social and cultural factors. To this Charles Beard added the need for including economic developments. The great depression of the 1930's stimulated interest in economic history and drew attention to the impact of technology. Even more recently, a small but growing group of trained historians has been delving into the history of science and technology. Their researches have already demonstrated how little we once knew of the history of science, particularly of the period before the beginnings of the so-called Industrial Revolution.

As new areas are explored, historians rewrite history, drawing upon their own understandings and experiences and integrating latest findings with the old to provide fresh insights in the continuing effort to make the present intelligible. From these efforts a new synthesis emerges, new hypotheses are formulated, and man seems that much closer to a proper understanding of his social, economic, and political institutions. In the opinion of the author of this chapter, the next—if not the present—generation of historians will give science and technology a far more prominent place in the casual pattern of past events which have shaped the present and help us understand how our social world came to be as it is.

Some 200 years ago the Industrial Revolution began in England and before long left its mark upon all Western civilization. Today few areas of the globe have escaped its impact, even the frozen North and the subcontinent of Antarctica have been made at least temporarily inhabitable by the products of industrialization. It has long been fashionable in one-volume histories of recent times to devote a chapter to the Industrial Revolution, a chapter that tells of a relatively static civilization that was suddenly revolutionized by the genius of a handful of inventors. These included the inventors of various elemental textile machines (but usually not including the most noteworthy of all, the Frenchman, Jacquard), the inventor of the steam engine, and the inventor of the railroad locomotive. Scientists received but scant attention, and Eli Whitney was acclaimed only for his invention of the cotton gin—not for his development of interchangeable-part manufacture. An occasional author might mention the development of machine tools, but few paid any attention to innovations in the field of industrial chemistry. Then in a concluding section, or perhaps in another chapter, these books would point to the development of factory production and the urbanization of our working population, leading to the need for reform in the form of factory acts and other social legislation. Having thus impressed upon the reader the great significance of the Industrial Revolution, most of these books then returned to the "more proper" subject matter of history: politics, diplomacy, and war.

Fortunately, most high school and college textbooks have corrected the misimpressions and downright historical inaccuracies that once characterized the treatment of scientific and technological developments. But it is still not uncommon to wrap up the whole subject of industrialization in a chapter or two, and thenceforth to ignore it, except for an occasional remark, until the revolutionary age of nuclear energy opens.

Today, we live in an age dominated by science and technology. From the electric clock that awakens us in the morning and starts our coffee pot percolating to the foam rubber mattress on which we sleep at night, our entire 24-hour day is lived in association with the products of modern technology. Generals and admirals are completely dependent upon the weapons devised in scientific laboratories. Politicians and statesmen hold office because of their skillful use of modern media of communication, all of which have achieved their present efficiency thanks to modern science. Moreover, extremely rare is the worker, whether in artistic, productive, or service enterprises, whose labors are unaffected by the technology of our age. But most awesome of all, we now know that we live in an age when man's knowledge of science makes him capable of destroying himself, if not the planet upon which he lives. With all aspects of living—politics, economics, occupations, even the arts and religion—subject to the impact of science and technology, it seems clear that within the next 50 years history will be rewritten to give science and technology the more central position it properly deserves as a determinant of our way of life.

SCIENCE IN SOCIAL STUDIES: A PROBLEM OF CONTENT

One big question facing social studies teachers is how much understanding of science and technology must be learned in order effectively to interpret the impact of science upon society. In view of the apparent distaste for the study of science, it is not surprising to find many social studies teachers talking in the manner quoted at the beginning of this chapter. "We have to know nothing of science to deal with its social implications," they say. Yet there is reason for believing that this very lack of knowledge and understanding of science accounts in part for the less effective teaching of such topics as the Industrial Revolution, which apparently is one of the less popular subjects with social studies teachers. Year after year, to cite one bit of evidence, the author of this chapter has observed that no matter how little actual teaching a student teacher is permitted to do he is invariably asked to handle the unit on the Industrial Revolution, not because the student teacher has any particular competence in that subject but because the unit on the Industrial Revolution is such an unpopular topic with the regular teacher.

At the other extreme from those who contend that no knowledge of science and technology is needed is a minority, admittedly small, of social studies teachers who argue that a considerable understanding of science and technology makes for more effective and realistic teaching as they pursue the goal of trying to make the social world intelligible. And they point out, too, that many students who otherwise show little interest in the social studies come to life when technological developments are meaningfully integrated with the subject matter of social studies.

Somewhere between these two extremes lies the answer to the question of how much and what kind of competence in science social studies teachers should have. And while social scientists still grope for an answer to that question, they must also consider how best that competence can be achieved. Answers to these questions will be forthcoming only after considerable discussion and experimentation, involving the cooperative endeavors of research scholars and teachers in both the natural and the social sciences.

A first reaction to the proposal for cooperative planning and experimentation by scientists and social scientists is likely to be that the two disciplines never have worked very closely together and there is little reason to expect them to do so in the future. The social scientists, of course, might be willing to make the effort, but the scientists are little interested in our field, and obviously feel at home only in their laboratories with their slide rules and complex experimental equipment. Such a reaction is not necessarily valid.

Certainly the development of the atomic bomb has awakened a real sense of social responsibility among scientists. Never before have they been so conscious of the impact of their research upon society. With the awakening of that consciousness they have, in a sense, participated in the world of the social scientist. They are becoming very much concerned with the social consequences of scientific discovery, and are seeking to develop in their fellow men a better understanding of the nature and role of science and its associated technology in our complex and interdependent society. Many of the scientists who are involved in teacher education are well beyond the pioneering stages in their effort to teach science not just for a knowledge of science per se, but so young people will become more effective participants in the civic life of our democratic society. The author of this chapter feels confident, then, that natural scientists, both in research and in teaching, will welcome overtures from social scientists in the development of educational programs that will lead to a better understanding of the impact of science and technology upon our way of life.

Before proceeding further, it might be well to review briefly the meaning of science and technology as used in this chapter. Theoretical and sometimes practical distinctions can be drawn between "pure" and "applied" science. Pure scientists are presumed to be interested only in uncovering more of nature's secrets concerning our physical and biological universe, without any concern for the practical consequences of their discoveries. Applied scientists supposedly utilize the findings of pure scientists for practical ends, and carry on research not for its theoretical considerations, but to improve upon or develop new processes and products that will satisfy man's material wants. But these distinctions are not particularly relevant here, though they may be pertinent to an understanding of the contributions of theoretical science to modern technology.

Technology is a word in large part synonymous with applied science, though in common usage it is a somewhat broader term. People usually think of almost any of the products of factories as being the products of technology, including such diverse things as plastics, antibiotic drugs, lawn mowers, zippers, and hearing aids. Products of technology also include such engineering achievements as suspension bridges, skyscrapers, superhighways, and ocean liners.

Inventors are usually assumed to be scientists. Obviously, most successful applied scientists are inventors. Many pure scientists are also inventors (applied scientists), inventing equipment with which to carry on their experiments and for example, in the case of the development of the A- and H-bombs, they not only provided the theoretical foundation, but also participated actively in the process of transforming theoretical conceptions into practical, useful realities. On the other hand, whoever first toyed with a piece of wire and fashioned it into the now ubiquitous paper clip can rightfully be credited with being an inventor and therefore a contributor to modern technology; but if he was a scientist it was largely a coincidence, for the paper clip could have been invented by any practical man without any knowledge whatsoever of pure or applied science. So it was with most of the men who invented the early textile machines we read so much about in chapters on the beginnings of the Industrial Revolution.

In this chapter, the terms technology and science are normally used without the niceties of precise definition. In general the scientist is considered to be one who enlarges our understanding of the physical and biological universe. The applied scientist, technologist, or inventor is one who may or may not utilize the findings of the scientist, but who generally employs empirical procedures to devise and produce those products of modern industry that elevate the material standard of living and provide means for enhancing our cultural well-being.

Science and technology have a tremendous impact upon society, and it is with this impact that social scientists are concerned. The problem, however, is first to define the competence in science and technology which social studies teachers should have in order properly to assess the social impact of science and technology, and second to consider how that competence can be acquired. Though well aware of the general reactions of social studies teachers whenever this question is raised, the author of this chapter feels, nevertheless, that the new generation of social studies teachers must develop more competence and interest in this area than has been true heretofore.

Competence in science involves (a) an understanding of so-called scientific method, and (b) knowledge of facts, principles, and generalizations drawn from the subject matter of science. In spite of a great deal of talk by social studies teachers about applying scientific method to the analysis of social problems, it is the author's contention that often social studies teachers are as naive in their conception of scientific method as they are in understanding of the subject matter of science. To the extent that this is true, it is by no means the fault of the social scientist. Following the lead of the natural scientist, social scientists have attempted to borrow and apply the concept of scientific method even though natural scientists themselves display confusion as to its meaning.

SCIENTIFIC METHOD: SOME MISCONCEPTIONS

In view of the widespread use of the term scientific method, social studies teachers should have some understanding of its meaning and limitations. Otherwise they may be deluded into accepting the false notion that social scientists need only acquire the skill of applying the formula of scientific method to social problems and all the problems will be solved, since it will enable them to close the cultural lag between scientific innovation and the development of social institutions. Fortunately, very little need be known about the subject matter of science to develop a more realistic understanding of scientific method.

Much of the social studies teacher's concept of scientific method derives from elementary laboratory exercises he once performed in secondary school science courses. Take, for example, an experiment involving the law governing the acceleration of a round object rolling down an inclined plane. Without exactly understanding the methodology of the procedure, he nevertheless was instructed to treat the law as an hypothesis. He took a marble or large ball bearing and rolled it down a gently sloping board, putting a mark on the board to indicate the location of the rolling body each second after it started rolling until it reached the bottom of the inclined plane. He measured the distance from the point where the ball started rolling to each of the marks on the board. Then he made some simple mathematical computations which demonstrated that the hypothesis had been tested and found accurate. Other students performed the same experiment with similar results. The hypothesis thus became a scientific law. He and the other students believed they had thereby applied the scientific method.

What did the students do that was supposedly scientific method? Certainly they had been objective. They had read the stop watch accurately as the seconds were ticked off; they had not been influenced by subjectivity as they marked the location of the rolling body each second; they had measured the distances carefully being anxious lest the distances not come out right, but notwithstanding their anxiety they had measured as accurately as possible; finally, when it came to the mathematical computations their emotions and desires could in no way influence the outcome of correct mathematical procedures. (How many times, however, did they cheat just a little bit in their measurements to make the answer come out right! Not proper scientific method of course, but they did not seriously believe that in testing the hypothesis they would find it wanting.)

In addition to being objective, what else had they done that is part of scientific method? They had used the experimental method—the controlled experiment—to test the hypothesis. To be sure, they hadn't devised the experiment that had been set up for them in their workbook. But they had followed a procedure that could be duplicated in any laboratory. Moreover, several students had conducted the same experiment and, except for those who had made mistakes, the results had confirmed the hypothesis. Objectivity and experimental method, then, are the backbone of scientific method according to what they learned in an elementary high school course. With that kind of background, the student of the social sciences, feeling that natural scientists have made so much more spectacular successes in their field than the social scientist has in his field, decides that the application of scientific methodology is the key to the natural scientist's success. One need only apply the same methodology to the social sciences and he will be equally successful! All the social scientist has to do is recognize and define his problems, establish hypotheses, test them objectively (though experimental method is often impossible or extremely difficult to implement), and arrive at valid conclusions. His problems are then solved unless or until new evidence or new conditions make it necessary to retest his hypotheses.

If, as the author maintains, the foregoing represents a naive notion of scientific method, what is scientific method? One answer is to be found in the words of one who played an instrumental role in the development of the atomic bomb, a scientist in his own right and an educator who, in the course of his many years as President of Harvard University, devoted considerable attention to the problems of secondary as well as college education. In delivering the Bampton lectures at Columbia University in 1952, Conant had this to say:

> It would be my thesis that those historians of science, and I might add philosophers as well, who emphasize that there is no such thing as *the* scientific method are doing a public service. To my mind, some of the oversimplified accounts of science and its workings to be found in the elementary texts in high schools, for example, are based on a fallacious reading of the history of physics, chemistry, and biology.[1]

Later in the same lecture he said:

> What is often defined as the scientific method is nothing more or less than an approximate description of a well-ordered systematized empirical inquiry. . . . by well-ordered empirical procedures it has been possible to make great progress in the practical arts. Such procedures are still being used in almost all branches of applied science.[2]

Granted many scientists, distinguished and otherwise, do not support Conant's position, his words, nevertheless, should command attention and lead to a reconsideration of the method or methods employed by scientists and technologists. There should be some understanding of what is meant by a "well-ordered systematized empirical inquiry." There is need to examine the role of theoretical considerations and to understand what Conant means when he says, "Only by the introduction of a theoretical element can the degree of empiricism be reduced." And perhaps even more important is the need to examine the various processes by which scientists develop hypotheses, for this is the one step that is so frequently slighted in discussing so-called scientific method and in presenting the formula for problem solving as found in social studies textbooks. Certainly, devising a rewarding and original hypothesis is not the product of applying a formula, yet in all probability the formulation of an hypothesis is the most crucial aspect of solving any problem whether it be in the natural or social sciences. Historians of science have found that scientists have no single method of developing hypotheses; moreover, scientists both in the pure and applied sciences have often resorted to highly *unscientific* thinking in developing hypotheses.

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[1] Conant, James B. *Modern Science and Modern Man.* Garden City, New York: Doubleday Anchor Books, 1953. p. 35.

[2] *Ibid.*, p. 46, 47.

Returning momentarily to the laboratory exercise involving the rolling ball and the inclined plane, note that the laboratory exercise at best only illustrated experimental method. The development of an hypothesis was not involved, for the students were presented with the hypothesis—which they knew was actually a scientific law. Moreover, it was a highly simplified experiment involving only two variables, time and distance, and there was no problem of controlling other variables. True, the experiment was performed in a strictly objective manner, but this too represents oversimplification. Measuring instruments seemingly lend themselves to a high order of objectivity, but in more complex experiments in the natural sciences, the interpretation of the readings of measuring instruments may involve subtle degrees of subjectivity that are highly significant in assessing the outcomes of experimental procedures. Such factors of interpretation were completely lacking in the simple high school laboratory experiment.

Competence in Science and Technology: For the Study of History

An understanding of the methods of the natural scientist, then, is a competence social studies teachers should have. It is a somewhat more complex subject than many social studies teachers have believed it to be, yet the basic concepts are not overly difficult to comprehend. Far more difficult to answer is the question of how much competence social studies teachers should have in the subject matter of science and technology in order properly to interpret the impact of developments in those fields upon our social world. Any answer to this question, to the extent that it attracts attention, is likely to be highly controversial. Actually, as in the learning of all things, no answer can be given in the sense of outlining a certain minimum of facts and theories that all social studies teachers should know and understand. Individual differences in learning are just as pronounced among teachers as among students, and those same individual differences affect the success with which knowledge can be applied to the enrichment of teaching.

No attempt will be made here to outline a body of scientific subject matter, an understanding of which should provide a minimum of competence for social studies teachers. That task can best be accomplished through the cooperative thinking of numerous teachers and scholars in the science and social science fields. Instead, examples will be cited from the social studies content of history and modern problems courses to illustrate the need for this competence.

As an initial illustration, take a specific graduate course on selected topics in the history of Western Europe. One of the topics on which several weeks are spent deals with the Industrial Revolution, and in conventional manner begins with the British inventors of the eighteenth century. In quite unconventional manner, however, the class begins by reading a section from a fairly well-known tenth grade world history textbook. The section occupies about one and one-half pages, including illustrations, and traces the developments which ultimately led to the invention of the steam engine by James Watt. The passage begins with reference to the scientific knowledge upon which the development of the steam engine depended, describing how Galileo questioned the assumption that "nature abhors a vacuum," and how Boyle's experiments led from an analysis of the weight and pressure of the atmosphere to a study of the pressure of expanding steam which was merely water in gaseous state. A single sentence then mentions how Newcomen built a workable steam engine which was so wasteful of fuel that it could be used only at mines where coal was very inexpensive. Finally, according to the text, James Watt, after systematic study, developed the separate condensing chamber that made a practical success of the engine. Watt, the textbook states, also developed a system for letting steam in and out of both sides of the piston, and then invented a way of converting reciprocating motion into rotary motion, thus making his engine adaptable for use in factories. Incidentally, no mention is made of Watt's governor which regulated the speed of his engine, a device of considerable significance to those interested in the historical development of automation.[8] The passage closes with an illustration of Watt's engine.

After this section is read to the class, the graduate students are asked how many understand the passage; perhaps a quarter of the class replies in the affirmative. But when asked how many understand it well enough to answer questions their tenth-graders might ask if they were teaching it, only one or two students respond affirmatively. They are the only ones who can give reasonably satisfactory answers to such questions as: What is meant by the textbook's statement that Galileo, in studying how high a vacuum pump could lift water, concluded there was a limit to nature's abhorrence of a vacuum? What is meant by the statement about the weight or pressure of air used in the first steam engine? What is a condensing chamber? Why is Watt instead of Newcomen called the inventor of the steam engine? Where are the condensing chamber, the piston and cylinder, and the boiler in the textbook's illustration of Watt's engine?

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[8] Writing on the subject of automation, a member of the Atomic Energy Commission pointed out parenthetically, "Automatic control, of course, is as old as the Industrial Revolution, for the *decisive new feature* of Watt's steam engine was its automatic valve control, including speed control by a 'governor.'" (Italics added.) Von Neumann, John. "Can We Survive Technology?" *Fortune* 51: 106-108, 151; June 1955. For a review of Dr. Von Neumann's life and work, see: Blair, Clay, Jr. "Passing of a Great Mind." *Life* 42: 89; February 25, 1957.

Various conclusions can be drawn from this experience with graduate students, all of whom are preservice or inservice teachers. Many will maintain that the textbook authors should delete almost all of the material on James Watt and merely indicate that Watt, building upon the discoveries of scientists and the prior experience of men who attempted to design a steam engine, was the first to construct a steam engine suitable for use in factories. Some will say the trouble lies in the textbook account which is overly condensed and alludes to ideas and concepts without adequate explanation. Others may feel this subject should best be handled by having a mechanically or scientifically minded student make an oral report on Watt's contribution to our technological age. And a very few may conclude that teachers themselves should have the necessary background to give meaning to this passage.

One year a young woman in this class surprised everyone by demonstrating her complete understanding of this material. Another student asked her if she had had a lot of science as an undergraduate. "No," she said, "I had no science at all in college; I learned all about it in ninth-grade general science!" This statement illustrates how little actual technical knowledge need be known in order effectively to teach about Watt from this particular textbook.

On the other hand, a little further knowledge can considerably enhance one's treatment of the subject. The development of the steam engine, for example, makes an excellent case study of the process of invention. It clearly demonstrates the old but reasonably valid statement that necessity is the mother of invention. It shows how inventors normally build directly or indirectly upon earlier scientific discoveries. It illustrates the generalization that most invention is the work of numerous individuals, each of whom makes some contribution until finally one of them makes an economically usable product and is therefore credited with being *the* inventor, notwithstanding the many who contributed to his success and the innumerable others who subsequently helped perfect the basic invention. As a case study, the processes Watt used illustrate very effectively the methods of the scientist-inventor. He used the controlled experiment in a university laboratory to test his hunch (hypothesis) that the Newcomen engine wasted the greater part of the steam's energy in the process of warming the cylinder which was cooled with each stroke of the piston. Having thus confirmed his hunch, he thought about the problem for two years before the idea flashed into his mind on the now famous Sunday walk (scientific method?) that a separate condensing chamber would make it possible to keep the cylinder always warm. This idea (hypothesis) was also tested in a controlled laboratory experiment before he took out his first patent on a "machine to raise water by fire." Finally, this study illustrates the dependence of the scientist-inventor upon the machinist who makes a reality of an inventor's idea, for Watt's first working model was a dismal failure. Only the use of Wilkinson's new cannon boring machine made possible the construction of the cylinder used in the first successful Watt engine.

The case study might stop at this point, but it could be continued to show that, although today's reciprocating steam engine is still basically the engine developed by Watt, scientists have quite successfully pursued the persistent goal of all engineers, namely, to make any machine ever more efficient. The Watt engine weighed too much per horsepower and consumed too much coal per horsepower per hour to be used in boats and vehicles. But step by step, efficiency was increased until, for example, the engine could be used in river boats, then in trans-Atlantic vessels, and finally in ships crossing the Pacific. Ultimately, the reciprocating engine reached a point beyond which no greater efficiency was possible. Today, new power producers, such as the steam turbine and the diesel engine, have proven so much more efficient that the highly perfected engines based on Watt's invention have largely been retired from service.

Experience in this course proves little except that relatively few teachers have the background or interest to do justice to topics involving the history of science and technology. Some few students, however, have experimented with introducing this kind of material in their high school classes and report a surprisingly high interest level—much higher than has been manifest in the course for social studies teachers just described. But interest level is hardly a proper criterion for justifying the inclusion or exclusion of certain topics or emphases. Teachers who have included this kind of material feel certain that it has contributed a richer, more mature understanding of the social consequences of technological innovation. And they feel that without this knowledge of scientific and technological developments, they are ill prepared to understand and plan for the impact these developments will make upon our social world. This, then, not only provides justification for including such material within the proper subject matter of the social studies, but also makes its study virtually mandatory if we are to fulfil the professed aims of the social studies.

Turning now from a specific illustration in a graduate course to examples in social studies content where background in science and technology can be helpful, note that most world history and some American history courses begin with geographic and geological analysis, followed by an account of primitive man's long climb to the status of a civilized being. Political and social organization played a part in this story, but more significant was the application of man's intelligence to problems of a technological nature. When advances in these areas had been made, man reached the point where more complex social and political organization became necessary. In the process of becoming civilized, man learned how to use fire, how to domesticate animals, how to grow his own food crops and irrigate his land, how to fashion crude stone weapons and cutting tools, and how to use the power of his muscles more effectively with the aid of such elemental but highly significant inventions as the lever, the wheel, the pulley, and the screw. To these innovations was added the use of metals, probably beginning with copper, to which tin was eventually added, giving man his first alloy, bronze.

To one with little understanding of science and technology, these early innovations, most of which were the result of accident rather than deliberate effort, seem quite unimpressive. Yet they represent truly magnificent accomplishments. Primitive man's ability to appreciate their worth and adapt these inventions to innumerable tasks marks a tremendous step forward, and it was upon this seemingly simple technological foundation that our early civilizations flourished, raising man so far above the animal kingdom that he had the leisure to engage in cultural pursuits and devote considerable effort to such economically nonproductive enterprises as the building of great pyramids.

Another step forward resulted from man's effort to explain natural phenomena without recourse to superstition or religion. It was during the Greek and Hellenistic ages that science was born. Theoretical speculations ranged over such seemingly diverse subjects as the nature of the universe and the structure of matter. True, the practical consequences of this thinking, most of which was tested by logic rather than experimentation, was meager, but it represented a highly significant beginning in the development of theoretical science, without which technological progress would have been strictly dependent upon, and limited by, trial and error procedures. As Conant has said, "Only by the introduction of a theoretical element can the degree of empiricism be reduced."

One area usually neglected or certainly underemphasized in high school history is the engineering involved in the construction of homes, public buildings, temples, monuments, fortifications, roads, and aqueducts. The structure of buildings may be studied from the point of view of art and mention may be made of the invention of the arch and dome, but pupils learn all too little of the engineering that conditioned the basic architectural design of these structures and imposed limits upon size. At the same time we know so little of the techniques of construction that we fail properly to be impressed with the magnitude of the task imposed upon the builders of castles and cathedrals. We may be familiar with the statistic that Roman aqueducts provided the city of Rome with approximately 50 gallons of water per capita per day, but we have little knowledge or appreciation of the total process—social, political, economic, and technological that led to a water-supply system capable of meeting the needs of a modern American city. And when we study Roman roads, we know little more than that they were so well built as to survive to the days of the French Revolution. How many of us know why the Roman roads structurally were so superior, or on the other hand, why Roman road building techniques were not adopted by the British who found the solution for road building in the techniques of Macadam.

The Romans, however, like the Greeks and others of that age, never learned one simple fact that would have enabled them to use horses as draft animals. True, horses did draw chariots and some of the implements of war, but not until the so-called Dark Ages did man learn to design a collar that did not act as a choke collar when the load was increased. When we learn more of the technology of the period, this little publicized fact may take on more significance than we now attribute to it.

As we read today's textbooks, scientific discovery and technological innovation were at a standstill until the dawn of modern history around 1500 when Gutenberg, da Vinci, Copernicus, Galileo, and Kepler paved the way for the Industrial Revolution. While the period from the fall of the Roman Empire to the Renaissance is no longer referred to economically and politically as the Dark Ages, it nevertheless still seems appropriate to label the period a dark age in science and technology. The historians of science are just beginning their researches in this period, but they have made sufficient progress to conclude that the period is a dark one only because it has not been illuminated by the probing light of the research scholar. A glance at the list of inventions in the appendix of Lewis Mumford's *Technics and Civilization*[4] should readily convince any skeptics of the substantial progress that had been made before 1500. Neglect of these "dark age" achievements in school and college history will eventually be corrected, but probably not until scholars have pursued their investigations somewhat further.

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[4] Mumford, Lewis. *Technics and Civilization*. New York: Harcourt, Brace and Co., 1934.

Secondary school textbooks pay tribute to the work of such men as Galileo and Newton, men who in their attitudes, methods of investigation, and accomplishments ushered in the era of modern science. Yet how meaninglessly teachers develop those achievements unless they know something of the methodology and subject matter of science. One textbook, after indicating that Isaac Newton was the greatest name in science during the seventeenth and eighteenth centuries, provides only one additional sentence on Newton: "His discovery of the law of gravitation was the most notable idea that science received during these two centuries." Inevitably such a statement remains in the realm of verbalization—something for our students to memorize—unless we have some understanding of the law of gravitation and its widespread applications. Many are those who believe that the law of gravitation explains only the fall of an apple from a tree; little wonder they fail to appreciate or comprehend why Newton deserves even the modicum of space he usually receives in our history textbooks.

Standard treatment of the Industrial Revolution apparently still calls for the cataloging of a few inventors and their inventions, with the textile inventions of Kay, Arkwright, and Cartwright receiving the lion's share of attention. Presumably, then, as soon as these machines were invented they were immediately applied to industry, factories sprang up over night, and the Industrial Revolution was well under way. Such a treatment not only represents oversimplification; it represents also a distortion of the historical record. The heroic theory of invention has long since been discredited, for we know that almost all successful inventors have added but a small increment to the work of many predecessors; yet we often insist that our students memorize the names of inventors, their inventions, and the dates of the inventions (the date often being the date of the patent which actually may have preceded by several years the successful construction of the machine described in the patent). Perhaps some still feel that the discipline of this kind of memorization is worth while; otherwise, such memorization adds little to our understanding and considerable to our misunderstanding. Two hundred years ago, several decades may have elapsed between the date of an invention and its significant application in industry, and still more decades may have passed before the invention had significant use in other countries.

Slowly our textbooks—and thus our teaching—are making progress in presenting a more accurate picture of the process of industrialization. We are still doing very little, however, in assessing the impact of particular inventions upon technological progress. The best known of the textile inventions, for example, merely represented success in mechanical gadgetry by men who in most instances had no knowledge of science and may even have been quite unscientific in their methods. If we were interested in the process of technological innovation, we could hardly ignore Jacquard whose loom was conceptually of a far higher order than any of the British or American textile inventions of the period. It was Jacquard who first introduced the technique of feeding information to a machine on punched cards, making it possible for the machine to weave any of a variety of patterns without making any change in the machine itself, but simply by supplying the machine with a different set of punched cards containing different instructions. In this age of automation, engineers are striving to apply this same technique more widely, still making use of punched cards, but also using other devices such as the magnetic tape for feeding instructions to the machine. Better understanding of science and technology on the part of social studies teachers will not automatically guarantee a more valid reading of this aspect of history, but it certainly will help to correct the misimpressions which have been taught and enable man to move more rapidly in the effort to keep pace with the cutting edge of scholarship.

Beyond the early stages of the Industrial Revolution, knowledge of the history of science and technology is more complete. Even so, most history textbooks give it scant attention but concern themselves almost exclusively with social implications. They examine the consequences of urbanization, but give no attention, for example, to the science and technology that made the modern industrial city possible. Without improvements in water supply systems, sanitation, and the science of medicine, cities would have been breeding grounds for innumerable contagious diseases; without refrigerated ships and railroad cars, cities would have been inadequately supplied with meat and dairy products; without elevators, borrowed from the mines and equipped with safety devices, cities would lack the third dimension of the modern skyscraper; without the development of urban rapid transit facilities, workmen's homes would still be built within the shadows cast by the factories in which they worked; and without the development of the long-distance transmission of electrical energy, large industrial cities would still flourish only where coal was inexpensive or where water power was available.

In this age of electricity our textbooks invariably give Edison credit for inventing the incandescent light and establishing the first central power station. But little further attention is given to significant developments in the electric power industry, one of which followed very closely after the opening of Edison's first power station. A modification of the induction coil led to the invention of the transformer which is as fundamental to the electric power industry as the vacuum tube is to electronics. The little publicized invention of the highly efficient and versatile transformer should rank among the great innovations of all time. When it is used with alternating current, voltages can be stepped up and stepped down, making possible the transmission of electrical energy over hundreds of miles with relatively little line loss. Electricity can be delivered to customers at any desired voltage, and the customer with his own transformers can step voltages down to the six volts used to ring door bells or up to the thousand or more volts required in home television sets. Thanks to the alternating current transformer and to the invention of water turbines, the power of falling water can be harnessed in remote areas and that energy transmitted great distances for industrial and domestic use.

COMPETENCE IN SCIENCE AND TECHNOLOGY: FOR THE STUDY OF CONTEMPORARY PROBLEMS

Countless other examples could be cited from the history of science and technology in which some elemental knowledge of science would make the teaching of history more effective. The same is also true of courses that deal with the problems of contemporary society. Perhaps one of the most persistent of contemporary issues is the farm problem which is a complex of political, economic, sociological, international relations, and technological factors. At the beginning of the Industrial Revolution four farm families were needed to provide sufficient surplus to feed one nonfarm family. Today in the United States, one farm family can supply a food surplus sufficient to feed 20 or more nonfarm families; since World War II productivity per agricultural worker has been increasing at a rate greater than the productivity of any other worker, yet with existing conditions of supply and demand for farm products, the productivity of the agricultural worker in dollars and cents is less than that of industrial workers with comparable skill. Scientists and technologists strive to increase agricultural productivity and therefore seem to be working at cross purposes with political economists who are striving to achieve conditions of supply and demand that will give the farmer a larger share of the national income. In the short run this quest for more efficient production may seem pointless, but in the long run man faces the increasing pressure of population upon food resources. Amidst echoes of neo-Malthusianism, he realizes that he can maintain existing standards of appetizing and nutritious diets in the future only if food producers use existing arable land more efficiently and at the same time develop techniques for using land now considered marginal or completely unsuitable for agricultural purposes.

Until 1840, empiricism governed man's efforts to increase the farmer's productivity. In that year, Justus von Liebig published his monumental volume on plant and soil chemistry, and thus ushered in the new field of agricultural science. Subsequent researches in the chemistry of plants and soils have led to the development of highly significant chemical fertilizers, to scientific methods of determining the best crops to plant in particular soils, and to the cultivation of dry lands once believed suitable only for cactus. Meanwhile, scientific breeding of crops and livestock has made a substantial contribution to agricultural productivity, and the makers of farm machinery have been so successful that present capital investment in such equipment in the United States exceeds the capital investment in the entire steel industry. Without some understanding of the science and technology involved, how can teachers or their students properly understand and appreciate the means by which fewer and fewer farmers are producing unsalable food surpluses notwithstanding the considerable increase in the consumption of agricultural products since the beginning of World War II? How otherwise can man anticipate future developments as he evaluates current proposals for "solving" the farm problem?

Another topic in problems courses requiring some background in science is the conservation of natural resources. Soil conservation is often thought to be largely the farmer's problem, though it is far too large a problem for him to solve by himself. The conservation and proper utilization of water resources directly affects all of us. We need water for domestic use, water for recreational purposes, water for industry, water for irrigation, water for power, and not least of all, water for air conditioning. Except in arid regions, obtaining an adequate supply of water was once no great problem. Now, even where rainfall is abundant, man finds the water table lowered until in some places it is almost out of reach while the thirst of rapidly growing metropolitan areas can be quenched only by tremendous investments in chains of reservoirs and associated aqueducts extending 100 miles or more from the metropolis they serve. The conservation of coal, oil, and gas, and the metallic minerals presents a variety of problems, some of them affecting only future generations, but others affecting us directly. For example, it becomes necessary to reopen mines once closed in order to extract the remaining low-grade ores once considered too poor for economic use. In formulating social policy relating to the conservation and use of these resources, many complex issues are involved, some economic and political, others scientific and technological. Citizens in a democracy cannot be expected to have expert knowledge of these issues, but they must have sufficient understanding to interpret available data and pass judgment on the proposals of experts in various fields. Social studies teachers would be doing the cause of democracy no favor to draw a line at the boundaries of the subject matter normally included within the social studies and say that other data are of no consequence. Failure to consider the scientific and technological would mean ignoring data that might well prove indispensable to intelligent civic action. Such failure would, therefore, be inconsistent with the professed aim of educating students for democratic citizenship.

The subject of television often comes within the scope of modern problems courses. Teachers may be concerned with evaluating its political impact, or with the quality of its programs. On the other hand, students may want to investigate the alleged trend toward network monopoly or the problem of making more channels available for TV stations. Although the development of a limited number of large TV networks is, to a considerable extent, the consequence of economic realities, it also derives in part from the science of radio communications. The situation is similar to the problem of making more channels available for telecasting. Society, exercising its controls through the Federal Communications Commission, claims the radio waves as public property to be used for the public welfare. This is done not only because policing of the air waves is necessary to prevent utter chaos, but also because there is limited space in the radio spectrum. Theoretically this space is not for sale but is assigned to specific individuals or corporate bodies to use for the public welfare. The technical problems involved in assigning frequencies and licensing stations and operators are tremendous, but some understanding of the science of radio, elementary though that knowledge may be, is of considerable help in assessing the policies of the FCC and understanding the development of telecasting in the United States.

As a final illustration, consider the unit on labor that is so often included in modern problems courses. This may well involve a study of one subject that has always been of great concern to labor: so-called technological unemployment. From the strikes of the Luddites in early nineteenth century England to the present, workers have often been hostile to the introduction of labor-saving machinery. From the long-range point of view their fears have proved groundless, for machinery has increased the productivity of labor and thereby raised their standard of living. Nevertheless, labor-saving machines can disrupt employment for specific workers and cause no little hardship. The social problem involved, then, is not one of inhibiting technological change, but of promoting policies that will mitigate the problems of adjustment. As a case in point, society now faces an innovation that some labor leaders would have us believe means a fearful amount of technological unemployment and a complete retraining of vast numbers of workers for new skills. Automation, it is said, will mark the beginning of a new industrial revolution. It is not a question of resisting automation, these labor leaders say, but of planning the training and placement of labor to anticipate the reduced demand for certain skills no longer needed when automation supplants existing procedures.

In spite of the vast literature on automation, there is as little agreement on the meaning of the term as there is on its implications. On the one extreme some maintain that automation means merely the introduction of more and more automatic machinery, a continuing process that began with the Industrial Revolution and will continue into the future at an accelerated pace. At the other extreme are those who see in automation a completely new type of factory staffed only with a few highly skilled engineers, but otherwise without workers. This condition will be true not only in plants turning out endless quantities of identical consumers' goods, but also in plants of the machine-tool industry producing individual pieces of machinery, each one different from the other and tailor-made to meet the precise specifications of a particular customer.

But whatever the definition, automation is already established in some industries. In Detroit one finds automation not in the plants producing Lincolns or Cadillacs or even Buicks but only in the plants engaged in the highest order of mass production, the plants making Fords and Chevrolets. There automation is linked primarily to the concept of continuous-flow production, for example, proceeding from a rough casting to a completely machined engine block without human handling. The boring and planing machines may be new in design but not in principle. What is new are the machines that move the casting from one machine to another and position it for the variety of operations performed upon it. These are by no means plants without workers, though the workers are somewhat fewer in number and do not display the brawn that was once required for guiding and moving the heavy castings. These are plants, however, with machinery of very considerable cost, so costly as to be uneconomical except in the production of the most popular cars.

Perhaps the best example of automation can be found in the oil refining industry where highly complex equipment, operated by a handful of skilled technicians and engineers, converts crude oil into finished products without appreciable human intervention or the exercise of human skills. Not only does this process illustrate continuous-flow production at its best, but it also illustrates the application of the feedback principle to provide quality control far more precise than could be accomplished by the most skilled of workers unaided by automatic devices.

But automation is not confined solely to production. Office machines when properly instructed by their operators can store and select information more accurately and efficiently than the best of clerks, while electronic computers, often erroneously called electronic "brains," perform tasks in seconds or minutes that would defy whole batteries of skilled mathematicians. This is not because the computer is smarter than mathematicians, but because it can perform thousands of simple addition, subtraction, memorization and selecting operations in less time than it takes to read this sentence. Automation, then, can be found in factories, in offices and in research laboratories. Eventually it may also be found in service enterprises. Perhaps, for example, we may one day make up our shopping list at home by punching holes in "IBM" cards, drive to the supermarket, reach out through our car window and insert the punched card into a slot, open one of the car doors, and in a minute or two see a carton rolling down a chute and into the car; the carton, of course, will contain our groceries and an itemized bill already charged to our account. Unfortunately, scientists will have launched successful earth satellites before this happy day arrives for the patrons of supermarkets.

Automation may be difficult to define, but it is already a part of American industry, something for labor in particular and society in general to reckon with. To talk sense rather than nonsense about automation, social studies teachers need not know very much that is scientific or technical. From magazines such as *Fortune* and *Scientific American* they can obtain some understanding of the basic principles believed to be inherent in automation. From these same lay publications they can also observe the application of automation in present-day industry. With background thus gained, teachers of the social studies can satisfactorily lead discussions on the significance of automation to labor and industry, the cost and benefits of automation, and whether industry, labor, and/or government should engage in preplanning to mitigate the economic and personal dislocations that may result from the wider application of automation to industry and other aspects of the economy.

These few illustrations from history and modern problems courses are not intended to review the history of science and technology or evaluate their impact upon contemporary society. While some of the illustrations may draw attention to neglected areas in the social studies and may serve in part to document this writer's thesis that scientific and technological developments deserve a more central position in an analysis of the dynamics of history, the main purpose in reviewing this material is to indicate how a relatively modest knowledge of science can enhance our teaching of the social studies. The treatments of technological topics can thereby be removed from the realm of verbalization and we can more intelligently distinguish between the significant and the insignificant. Moreover, effective teaching in this area will develop new interests among more students, many of whom for the first time will find real meaning in the subject matter of the social studies.

TEACHER EDUCATION: THE PROBLEM OF INTEREST

One question remains to be considered in this chapter: how social studies teachers can develop the competence in science necessary for the effective teaching of topics such as those indicated above. Logically the answer to this question lies in a consideration of the preservice and inservice training of teachers, but possibly more crucial than formal training is another factor that may fall more properly within the province of the psychologist.

As this writer sees it, a large majority of social studies teachers simply are not interested in science or its related technology. They insist they have long since forgotten whatever science they learned in high school or college—and it's all very technical anyhow, they claim, far beyond their comprehension. With this attitude, it is not surprising to find them building a wall between themselves and anything scientific or technological that may come their way. They easily convince themselves that they have no responsibility for developing an interest in science; certainly they have no responsibility for integrating anything scientific with their social studies teaching. Let the science teachers handle science; social studies teachers have their hands full with the social studies without adding to already overcrowded courses of study.

Unless an interest in science and technology can be developed, those who feel that science has a real place in social education will make little progress. Perhaps, however, this lack of interest is not quite as real as it seems. In recent years the author has observed many social studies teachers who have learned enough of the science of optics to make skilful use of expensive cameras with interchangeable lenses. Others have become Hi-Fi enthusiasts and can speak intelligently on such subjects as audio frequency response, intermodulation distortion, and inverse feedback; a few can even assemble their own Hi-Fi equipment from kits. And in this age of do-it-yourself, many are finding to their amazement that they can accomplish wonders, notwithstanding their former insistence that they had absolutely no mechanical aptitude. If the ice can be broken, interest in science can be developed, and with increased interest, social studies teachers will find that the actual science involved is neither too technical nor too difficult to comprehend. Moreover, they will find that as their knowledge and understanding increases, so will their appreciation of the role of science in social education.

Another factor related to the problem of interest is our attitude toward specialization. In an age of specialization, we all feel a responsibility for understanding what is properly related to their own specialty no matter how much study it may take, or no matter how difficult it may be. At the same time we feel no obligation to pursue our study of some other field when something a little difficult appears; rather than master it, we turn from it, allowing it to block the path of further understanding. But in recent years a reaction against overspecialization seems to be in the making. Educators are stressing the values of general education, while scholars as well as teachers are developing the theme of the interrelatedness of knowledge. Even as specialists in the social studies, then, some teachers are becoming conscious of overly narrow specialization and at the same time are recognizing the interrelations between their field and others. It is no longer a question of whether there should be science in social education, but of how much and what kind of science is pertinent to an understanding of the social studies. Once convinced that aspects of science and technology are within our field, social studies teachers will undoubtedly feel a professional obligation to develop at least limited competence, and as that competence develops interest should change from a negative to a positive factor in the effort to develop the background necessary for incorporating aspects of science in social education.

TEACHER EDUCATION: THROUGH GENERAL EDUCATION PROGRAMS IN SCIENCE

When considering how social studies teachers in their formal preservice and inservice training can gain the necessary understanding of science, one is tempted to turn first to the general education program in science. Since World War II the general education philosophy has made considerable headway and has left its mark upon almost all of the traditional disciplines. In science education colleges are experimenting with several patterns, of which three seem most popular. One program of general education in science is built essentially around the traditional subject matter of science, but with definite modifications in organization and technical requirements to adapt to the needs of students who will not major in science. A second pattern is organized to emphasize those aspects of science that should contribute to civic competence, perhaps giving attention also to science for everyday living. A third pattern in general education science courses emphasizes the historical development of scientific knowledge and thought, and is much concerned with the processes or methods by which scientific knowledge has been advanced. This treatment involves not only an analysis of how particular discoveries are made—the methodology of science—but also concerns itself with the accumulation and exchange of knowledge and the way in which accumulated knowledge contributes to further discovery and innovation.

Of the three patterns, the last two seem highly promising for social studies purposes. The second pattern should prove particularly effective in developing the competence in science that would be applicable to the teaching of modern problems or contemporary history courses, while the third should be useful in integrating developments in science and technology with world and American history. Any good program of general education in science, however, should provide the background and interest that will facilitate and motivate continuing independent study of science and its technological applications.

Excellent though many of these science programs may be, most inservice teachers and a considerable proportion of preservice teachers will never have the opportunity to participate in them.[5] Furthermore, the content of these programs is selected to promote the aims of science education, not to enhance the understanding of the social sciences. It is obvious, therefore, that college social science instructors must take active responsibility for integrating developments in science and technology with the content of the social sciences. This is a formidable task. Few social science instructors have developed the interest and understandings necessary for meaningful teaching of the interrelations of science and social science. But still more important, textbooks and most specialized works—the reading materials that provide guidance for instructors and information for students—have hardly begun to incorporate material along the lines suggested in this chapter. Research scholars have made significant progress, but the inevitable lag between research and the development of new syntheses, coupled with the still greater lag between the acceptance of new interpretations and their publication in textbooks, leaves the instructor severely handicapped in his effort to keep pace with scholarship.

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[5] The science department at Teachers College, Columbia University, offers a course on the social implications of science and technology. Although it has been received enthusiastically by students, relatively few social science students have been persuaded to take it, and most of those who have enrolled in it have been doctoral students preparing for college teaching rather than secondary school teaching.

In spite of these difficulties, social science instructors can make a start, crude though initial efforts may seem. The importance of this undertaking is underscored particularly for those engaged in teacher education, for it is commonly accepted that teachers tend to teach as they have been taught. Instructors, unfortunately, must depend largely upon their own resources in organizing content and learning materials that relate science to the social sciences. They must be creative and use their own initiative, since only limited help will be derived from the fragmentary suggestions that can be found, here and there, in lay and professional literature. The end product will not be a comprehensive, nicely balanced organization, but a start can be made in the experimental process of developing courses of study that recognize the central role of science and technology in making our social institutions what they are today.

Basically, two techniques for implementing this goal seem most promising, and both have already been illustrated in this chapter. One technique is to analyze the nature and impact of scientific or technological innovation whenever it appears in our course of study, pursuing the study more intensively, and introducing related material to supplement the meager treatments found in our textbooks. Thus, for example, when mention is made of Newton's explanation of the falling apple, instead of stopping at this point as is customary, we should continue the study of Newton far enough to develop an appreciation for the totality of his contributions to scientific knowledge, and to relate his achievements to the cumulative process by which man gradually discovers more and more of the secrets of the physical universe.

The second technique is to employ the case method of teaching, which in a sense is a modification of the first, the main difference being that this involves still more intensive study, requires reading materials that may be available only for a relatively few topics, and involves an expenditure of time that necessarily limits the opportunities for applying this technique. The case method has long been successfully applied in law and business schools, and has been employed in some instances in the social sciences. The illustration cited earlier in this chapter concerning the invention of the steam engine is an example of a case study, one with which the author first experimented when teaching a world history class for secondary school students. Later it was adapted to college teaching, and subsequently received moral support and constructive ideas from Conant's little volume *On Understanding Science, An Historical Approach.*[6]

Conant addresses himself to the problem of giving college students in general a better understanding of science, and proposes the use of case histories to accomplish this goal. He points out, however, that the "greatest hindrance to the widespread use of case histories in teaching science is the lack of suitable case material." This limitation applies equally to the social sciences, in which instructors can apply the same technique, but with modifications that make the primary goal an understanding of the social implications of science rather than an understanding of science itself. Students must understand that a case study is merely a sample, that it is intended to be illustrative, that it is a device designed to give students an opportunity to study a selected topic in sufficient detail to appreciate its full significance, and that the selection of topics for this treatment is arbitrary, depending among other things upon the availability of reading materials and upon the difficulty of the scientific concepts involved. Although the instructor will find it an arduous and time-consuming task to build a repertoire of case studies, and although he will find at first that he must place undue reliance upon lecturing because of the lack of suitable reading materials, he should nevertheless find the case method peculiarly well adapted to the task of relating science to the social sciences.

Thus far the problem of science in social education has been treated as a problem in content, a problem of general education, a problem requiring the attention of social studies teachers at all levels of instruction. In this respect, no real differentiation is made between students in general and those presently engaged in or preparing for the profession of teaching. Although textbooks, professional organizations, and professional literature may guide the teacher into the teaching of new interpretations and emphases, and may encourage the introduction of new topics in the course of study, teachers basically build their subject-matter organizations around the facts, understandings, attitudes, and ideas they learned as students. If changes in content are to be introduced, the most efficient means for effecting change is to introduce the new materials in courses that are part of teacher education programs. An instructor in history or sociology at a teachers college can be reasonably sure that his students are destined for the teaching profession, but liberal arts colleges also contribute significantly to the teaching profession. Consequently, in considering the problem of content, any distinction between teacher education programs and programs in general education is largely theoretical and without validity in practice. It is a problem for all instructors, not just for those formally identified as being engaged in teacher education.

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[6] Conant, James B. *On Understanding Science.* New Haven: Yale University Press, 1947.

TEACHER EDUCATION: THROUGH METHODS COURSES

Instructors in education may also contribute to the process of modifying conventional content in the subject matter of the social studies. Courses in methods of teaching social studies invariably deal with the subject of aims and values. Any meaningful analysis of the goals of social education inevitably requires a consideration of the forces that are most significant in making the changing social world what it is. Certainly any discussion along these lines cannot ignore the impact of science and technology. While students should be free to develop their own ideas concerning the values of instruction in the social studies, at least they can be asked to give serious thought to the question of whether an understanding and appreciation of the impact of science and technology should be one of the controlling elements in the selection of content for social studies courses.

Methods courses normally give attention to organizational patterns or methods of teaching such as the problem method. The problem method is usually considered an application of so-called scientific method to the solving of social and personal problems. Although the treatment of problem method may be limited to a presentation of the five—or is it four or six—steps of the problem-solving formula, a more meaningful procedure is to relate the problem-solving method to scientific method. From a discussion along the lines indicated in the early part of this chapter, the instructor can then consider research methodology in the various social science disciplines, thereby paving the way toward a realistic understanding of the values and limitations of the problem method as applied in the social studies. This kind of presentation should distinguish between the work of research social scientists and the work of secondary school students as they apply the problem method; it should analyze the crucial step of formulating hypotheses, and should indicate that secondary students often get no further than the formulation of tentative hypotheses; it should distinguish between the kinds of problems for which conclusions are in the form of a "yes" or "no" and the kind of problems that require constructive proposals for action; and it should make clear that the problem-solving method often results in conclusions that fall far short of actually solving the problem in question. In short, students in methods courses should realize that the so-called scientific method provides no magic formula for progress in the natural sciences, and that its modification into a problem-solving method for dealing with social or personal problems similarly provides no magic formula for secondary school students to obtain precise and valid solutions to the problems of the citizen.

The methods instructor can encourage attention to science in social education by urging students to construct lesson plans and teachers' resource units on subjects involving science and technology. Such an assignment should present a truly creative challenge to an interested student, for he too can pioneer, sometimes with results that are just as promising as the work of a veteran teacher. Later when he is student-teaching or actually on the job, the student can test his lesson plan or unit, knowing that as a student he would have had the time to prepare more carefully than he now has as a teacher, and knowing also that his plans should have benefited from the prior evaluation of his instructor.

Finally, the methods instructor can use photographs on the subject of science and technology to demonstrate the particularly effective use of this form of visual aid. By itself, a diagrammatic picture of the Newcomen steam engine or a photo of a model of the early spinning jenny often provide little of educative value. If, however, the teacher will take the time to explain how the mechanism works, the picture no longer serves merely a decorative function, but becomes the instrument for developing an appreciation of the particular invention. Take, for example, a bulletin board with a picture of a huge hunk of machinery, underneath which was the caption, "The steam turbine generates power to light American homes and run the machines of industry." Alongside was a photograph showing the same turbine with part of its outer shell missing. The pictures, however, served merely to take up space on the bulletin board. Turbines were mentioned in class; students learned that the turbine was an important invention, but that was all, notwithstanding that at least one mechanically minded student in class was quite familiar with the workings of the turbine and knew why the turbine had replaced the reciprocating steam engine in modern generating plants. The two pictures served their decorative function for a time and then were retired. How easily they could have been used to explain this miracle of modern technology, a machine into which steam enters at 2000 pounds pressure and nearly hot enough to turn steel red (1100°), and 1/30 of a second later, having moved some 5000 "buckets," leaves the machine at a temperature lower than that of the human body and at a pressure less than that of the atmosphere, in the process converting approximately 98 percent of its energy into the motion that drives an electrical generator with the force of nearly 300,000 horses. The efficiency, the power, the precision of today's turbine is symbolic of modern technology. Visual aids, pictures that sometimes go unnoticed, can be employed with unusual effectiveness to help students appreciate the nature of this technology, thus enabling them more realistically to assess its impact upon society.

SCIENCE IN SOCIAL EDUCATION: EMERGING PROBLEMS IN TEACHER EDUCATION

It is often said that there is a lag of at least one generation between scholarship and the secondary school classroom. It takes time for new ideas to find their way from the minds of researchers to the notes of instructors and the pages of textbooks. And because science and technology are in a sense so foreign to the interests and intellectual backgrounds of social science instructors, only an optimist is likely to believe that the time lag involved in acquiring greater attention for science in social education can be reduced below normal expectations. The shortage of adequate instructional materials will undoubtedly continue to act as a block in the years to come. Even though some authors may write worthy manuscripts, publishers are not quick to publish unless there is demand, and at present there is seemingly too little demand for social studies materials that incorporate those aspects of science that give deeper meaning to a study of the social impact of science and technology.

On the other hand, there is evidence that some progress is being made. The advent of the A- and H-bombs has rudely awakened social studies teachers to the need for some understanding of science. Many social studies teachers in recent years have learned a surprising amount on the subject of nuclear physics, and social studies units on atomic energy are replete with colorful diagrams and accompanying text explaining the mysteries of nuclear energy. For reasons not yet clear to this writer, many of the younger generation of social studies teachers seem more mechanically and scientifically minded than was once the case. Could this be a dividend from military training which forces even the most inept into various kinds of mechanical and scientific training? Moreover, one may well be surprised at the number of professors of history, sociology, and economics who have a respectable knowledge of science, though too often they appear constrained not to reveal it to their students.

There are, then, serious obstacles that inhibit the introduction of new subject matter and new ideas into the course of study, but at the same time there is reason for believing that the obstacles to the more effective treatment of science in social education are by no means overwhelming. Those engaged in teacher education, because of their position of influence upon the minds of present and future teachers, have a very special responsibility. Instructors in teacher training can be as instrumental as any other single group in shaping the content of curriculums in our schools, and if change is needed, they can play a vital role in reducing the inevitable time lag between conception and implementation. Every instructor involved in the training of social studies teachers should examine the subject of science in social education, and if he concludes that the emphases of this chapter and this Yearbook are worthy of implementation, it is his responsibility to employ his ingenuity to organize his subject matter and education courses accordingly. The instructor of social studies teachers must be alert to the latest findings of scholarship, he must evaluate new ideas that relate science to social education, and must share ideas with others, informally in discussion and more formally in articles or in the preparation of learning materials.

Another problem that will emerge in teacher education if the emphases of this chapter are taken seriously is the problem of whether teacher training institutions can undertake successfully the task of training their preservice social studies teachers in the additional competence needed to deal effectively with science in social education. This is very similar to the related problem of whether preservice or even inservice teachers have the time and energy to develop background in science along with their study of the social sciences and the educational disciplines. All of these are expanding and ever-changing fields that require continuing study if teachers are to be reasonably up to date.

Not too long ago a good student of American and European history could study the psychology of learning, take a catchall course in the problems of secondary education and be considered well prepared for a career as teacher of history in high schools. Today the task of teacher education has become far more complex. Today there are social studies teachers, not history teachers. In accordance with the whims of programing procedures, they must be prepared to teach any of a bewildering variety of social studies subjects: any or all aspects of world and American history, various problems courses, economic geography, consumer economics, even psychology, personality development and vocational guidance. In the field of education they must have competence not only in the psychology of learning but also in developmental psychology; must be well grounded in educational philosophy and the history of education; must have the skills and the command of educational processes sufficient to develop new curriculums and engage in action research. And, to top all, teachers are urged to prepare for teaching in correlated, integrated, fused, or core programs. Is there any limit to the competencies required of teachers or to the multiplicity of tasks imposed upon teacher-education programs? Now comes the plea for social studies teachers to have more understanding of science and technology, a plea for still one more competency to be added to the back-breaking burden of teacher preparation.

Although administrators seems always to be looking for teachers who can teach well any of two or three subjects in unrelated fields, the author has long maintained that it is too much to expect a properly trained senior high school social studies teacher to teach equally well in another field, whether it be English or science or programs involving several fields such as "core." The social studies constitute an area of tremendous scope; they encompass a large number of disciplines each of which is subject to the continual impact of changing interpretations and the findings of countless scholars actively engaged in research. Furthermore within the scope of social studies is the study of current events. To maintain continuing competence in the social studies is a large order. It is more than ever an inescapable responsibility of the professionally minded social studies teacher. How can he be expected, therefore, to add to his tasks that of developing background and keeping up to date on the science and technology which have implications for the social studies?

A partial answer is to be found in the history of the teaching of any of the social sciences. New facts, new understandings, new emphases have continuously been added to each of those disciplines, but as new elements have been added, others have been subtracted. The details of military history no longer clutter up our history textbooks. The colonial period in American history receives much less space than it did even 50 years ago. Courses no longer devote much attention to the gold vs. silver battles in economics. In the study of international relations, the League of Nations receives but cursory treatment in order that major attention may be focused on the United Nations. So it is with countless topics that now receive only scant attention but were once considered of major concern in the study of the respective disciplines. If it is agreed that science and technology represent major factors in the shaping of present world culture, if in the years ahead they are destined to play an instrumental role in the changing pattern of social, economic, political, diplomatic, and military affairs, it would seem that social studies courses should make room for the more effective treatment of the impact of science and technology. In the process some conventional subject matter will undoubtedly be slighted or completely neglected, but this is nothing new in the history of instruction in the social studies.

The scientific competence necessary to teach for a better understanding of the social impact of science and technology falls far short of the competence required to teach subjects such as biology or physics or chemistry. It is a competence that can easily be acquired in the general education science courses required of all students in high school and college; it is a competence that can be maintained by an interested and inquiring mind, a mind that has the same concern for current developments in technology as for the latest political events in Washington. Teacher-education programs, then, need not be burdened with appreciable additional subject matter. Science, in one form or another, has long been included in the liberal arts or general education requirements of all colleges. True, some of those courses might be tailored to meet more effectively the needs of social science students. There is, however, no need for additional courses or additional requirements. All that remains is for social science instructors to integrate within their courses the subject matter needed for giving proper meaning to the social impact of science and technology.

Probably the most significant element in this analysis of emerging problems is the problem of leadership. Leadership is needed to bring the natural and social scientists together, and leadership is needed to diffuse ideas among those engaged in social science instruction. As was pointed out early in this chapter, social scientists by themselves will find it a slow process to analyze and select those aspects of science that are most significant in understanding the social implications of technology. Balance and perspective can best and most quickly be achieved if scientists and social scientists, research scholars and teachers can have a meeting of minds, a process, which, unfortunately, cannot be accomplished by a single conference, but only by extended formal and informal contacts over a period of time. We need the leadership to make this possible, and we will need leadership to diffuse and implement ideas that develop from this meeting of minds. Professional organizations such as the National Council for the Social Studies should play their part. Not to be overlooked, however, is the possibility that one of the fund-granting foundations may become interested and provide the dynamic force that will accelerate progress and support latent leadership that even now may be awaiting recognition and opportunity.

Will it be necessary, as usual, to wait an entire generation for these new ideas to make their way into the classrooms of America's schools, or can leadership and resources be developed for cutting short the seemingly inevitable time lag? The author of this chapter is hopeful that social scientists will be able to answer the latter part of that question in the affirmative.

CHAPTER XIII

A Look Ahead

John H. Haefner and Howard H. Cummings

The prime purpose of education in this country is to help pupils learn to live effectively in American society. All school subjects, the extracurricular program and the general life of the school are designed to achieve this over-all purpose. The social studies by their very nature are expected to play a central role in initiating children and young men and women into full-fledged membership in this self-governing and self-directing society. Such a role demands that social studies teachers analyze continually the kind of world into which their pupils are graduating.

The changing nature of contemporary society has been a major theme for educational writers during the last generation. There is no need to document the dramatic changes brought about by recent developments in science and technology, but three aspects of change should be carefully considered:

1. *Change* is not necessarily *progress*. Any teacher of mature years can readily perceive that things today are different from things as they were even a short decade ago. However, a careful evaluation must be made before he can answer the question, Are things better or worse than they used to be? Such an audit usually reveals gains and losses. Wonder drugs and an increased food supply are balanced by a growing fear of atomic destruction. Television increases contacts, but does it increase understanding? Distance has been reduced by jet speed, but have people been brought any closer together in spirit and understanding? The products of science are only as effective as the men and women who use them, or control and direct their uses. Real progress is human progress, not material progress. It depends not only on what man can learn and apply in the field of science but also upon the intelligence and goodwill with which he uses his new knowledge.

2. Ideas and institutions do not change at the same rate and there are some things that modern man, with all his knowledge, does not want to change. Few Americans would consider giving up the ideas and ideals which hold that human life is sacred, that all men have the "unalienable right to life, liberty and the pursuit of happiness," or that governments derive "their just powers from the consent of the governed." Social studies teachers are custodians of a great human tradition as well as proponents of change. Any social accommodation to utilize new discoveries must be made within the framework of an enduring value system.

However, because they seek a balance between stability and change, social studies teachers must be particularly sensitive to the cultural lag. There are archaic institutions, customs, usages and habits which are not buttresses for the value system and only impede progress toward better living through modern means. Here the advance guard of education must clear the way by providing new knowledge and new patterns for meeting age-old problems.

3. For centuries, there has been change based on scientific knowledge but the changes are becoming more inclusive and faster. Scientific data accumulate and new knowledge comes from the growing accumulation. If Leonardo da Vinci could return to the world today he would probably be astounded at the advances in science. However, he would probably not be surprised at all at the advances made in painting and sculpture. Accumulated knowledge does not magnify the power of the painter's brush or the sculptor's chisel but it does enter into the scientist's work in his laboratory. On the basis of a growing accumulation of scientific knowledge, an increasing number of scientists, and improved communication among scientific workers, it can be predicted that changes in the future will probably equal or exceed those occurring in the present.

The social studies teacher who studies the development of science and technology as an increasingly important force in the changing society in which he lives will probably want to consider the following:

1. The future scientist, doctor, engineer, and technician, is sitting in today's classroom alongside the future statesman, lawyer, social worker, and teacher. Can these future leaders and followers learn together about a common system of values, a method for solving future public problems and a common appreciation of the work which each will perform?

2. No one knows with certainty what the future will bring in the way of scientific discovery and accompanying social change but the society of the future will evolve as a result of decisions which men will make about public policy and not emerge automatically from a scientist's laboratory.

Faster cars may be made, but need they be allowed to travel on public highways? Improved television will probably appear but need it be used so largely for entertaining the young? Automation will grow, but need the rate of such growth interfere with full employment?

Such public decisions must be made for civic, social, economic and cultural reasons. In reaching these decisions, new scientific discovery with its technological implementations and accompanying know-how remains neutral.

The purpose of social studies instruction is to help pupils prepare to make sound decisions on questions of public policy in which scientific knowledge will be an increasingly important factor. How can the social studies teachers do this job?

Perhaps it is artificial and unrealistic to try to separate such a unified task into component parts, but an extended discussion of the whole problem soon becomes unwieldy. The over-all problem of better social studies teaching can be considered under three topics: (a) motivation, (b) method, and (c) materials or content.

MOTIVATION

In any teaching situation it soon becomes clear that learners are capable of acquiring rather complex skills and mastering difficult ideas if they are highly motivated. Conversely, for most pupils, low motivation leads to tedious learning with meager outcomes. Guidance studies of pupils in school frequently show that pupils are not interested in social studies. Follow-up studies of graduates frequently indicate that in the opinion of these graduates social studies were of little use to them in later life. These studies are in no sense offering conclusive evidence that the social studies program has failed. At the same time the results of such studies probably indicate that in many social studies classrooms, pupils are working under low motivation. Learning to live in presentday American society is an exciting experience. If the segment of learning provided by the social studies is viewed as dull or useless, perhaps an examination of the program is in order. The inclusion of more materials on science and technology, with the accompanying social, political and economic effects, might heighten interest and improve social education at the same time.

METHOD

The aim of the social studies has always been to teach pupils *How To Think,* not *What To Think.* A short review of three events in very recent history can be presented to underline the futility of providing pupils with long-range solutions. Before August 6, 1945, most Americans were anxious to avoid future wars but believed that war, for the foreseeable future, would remain an instrument of national policy for the great powers. Then with the explosion of the first atomic bomb over Hiroshima came the vision of a monopoly of a new weapon so devastating that no nation could risk an attack upon its possessor. But the feeling of security through atomic monopoly ended on September 23, 1949, when President Truman announced that it was clear now that Russia, too, had atomic bombs. For four years the public mind had operated in the relative security of an uncertain atomic monopoly; now it had to think in world situations of atomic rivalry. On August 12, 1953, it was announced that both Russia and the United States had hydrogen bombs and in the months that followed the knowledge of the full destructiveness of the atomic fall-out had to be absorbed by all citizens. It is clear that American citizens have had to change their *What To Think* with each new revelation of atomic destructiveness. Those who were able to learn *How To Think* in school were able to utilize their academic know-how to reach new decisions in a world where the nature of warfare changed dramatically at four-year intervals.

But teaching pupils how to think goes deeper than know-how for collecting and arranging knowledge in order to reach a decision. The very nature of a democratic society demands that each individual enjoy the maximum freedom to make up his own mind. The role of the school in a democracy is to strive for better decisions by teaching individuals more effective techniques for making up their own minds. The reliance on reason is one of the fundamental faiths of democracy and teaching pupils how to think is education's chief contribution to a society relying on freedom and reason.

It is the purpose of the social studies program to aid in the development of individuals who can think critically and constructively. This implies that they have command of "power knowledge." Power knowledge consists of a firm foundation of factual information, a mental storehouse of significant generalizations, and a thorough grasp of the evidence which supports these generalizations. Power knowledge implies also the possession of the *skills* of critical thinking such as the differentiation of fact from opinion, the ability to draw inferences from incomplete data, the ability to detect and compare relationships between knowledge acquired in the past and the problem confronting the individual in the present. It implies command of the skills of locating, evaluating and organizing new information in the solution of problems. Thinking critically is a complicated and sophisticated procedure that must be taught directly and skillfully. It cannot be taught by osmosis and it is too important to be regarded as a by-product.

THE CURRICULUM

Any proposal to expand the social studies curriculum with topics for increasing the understanding of the role of science in modern society will meet with a certain amount of resistance. Social studies teachers for a generation have felt the danger of being overwhelmed by the creeping curriculum. Over the years they have been asked to teach more and more things and to educate in more and more areas. (As the problems of modern society have increased, the teachers have sensed the fact that the "creeping-in" process has hardly completed its trial run; hundreds of national movements and countless individuals still have important jobs for the school to do.) A process of addition without substraction has presented the classroom teacher with a curriculum which is literally bursting at the seams. Yet, every teacher knows that there is more to come.

Science and technology have created many of the problems which the social studies teachers face. Increasing mechanization has eliminated young workers and there is a steadily decreasing demand for the ignorant and unskilled in the labor force. Add the two trends together. Since industry no longer wants young workers; and since there is an increasing demand for trained and educated workers, the answer is, Keep youth in school and teach them as much as possible. Science and technology have operated to strengthen an educational philosophy that free public education must be available, literally, to *all* the children of *all* the people. It is tending to add a mandate that all remain in school until the age of 18.

One of the proper topics for study in the social studies classroom might well be the technological developments that moved the 12- to 18-year-old boys from the plow and loom into the classroom. Other topics readily suggest themselves. The rapid growth of population, of which the youth group is the fastest growing segment, is possible because science has increased the food supply, improved our knowledge of nutrition and reduced infant mortality. A larger national income, the result of the greater productivity of trained men operating machines, has elevated the families of many of the pupils from the laboring class into the expanding middle class. All of these topics supply answers to the question, "Why are we here?" which any high school class may ask. Detailed answers to this question form the guidelines for orientation to modern society.

When some knowledge of the effects of science and technology on society are included in the social studies curriculum a difficult problem of selection is involved. The purpose of the social studies is to teach boys and girls how to live in the society into which they were born. One test for selection is, Can the schools do this job better than other agencies and institutions in society? A second question in the criteria is, What part can the social studies do better than other school subjects? If materials which explain the character of a scientifically directed society and the place of the citizen in such a society can meet the criteria stated above, there is a good case for integrating such materials into the social studies curriculum. If the school or the social studies cannot meet the requirements, the task should be left to the institutions or the subject fields which can.

A third problem in selecting social studies content is the necessity for building a curriculum which has coherence, unity and progression. Too often the present curriculum of the school has been revised piecemeal rather than as a whole. If new content is added to help pupils understand the scientific forces at work in the society in which they live attention should be given to each grade from kindergarten through Grade XII. The architects of the curriculum should think in terms of the total understandings, attitudes and skills that they want to see developed. Having decided on these objectives the next step is to use content and experiences to help pupils reach the objectives. At each grade level, content and experiences should be used which have meaning for children at that age. The teachers and their curriculum consultants should be content with that measure of development which can be expected of the learner at a given age. Some of the concepts of a science-influenced society fortified with concrete illustrations from pupil experiences may well act as a stimulus to a neglected area in social studies curriculum experimentation. Such a neglected area is the problem of a progression of concept-building in the social studies with the accompanying problem of the degree to which these concepts can be developed at each age level.

In view of the rapid changes since 1940 it is likely that a social studies curriculum which has made few changes since that date is inadequate for pupils today. Particularly there is an apparent need to reappraise the apportionment of time devoted to the historical past and to the problems of the present. While the problems of today had their origin in the past, their nature has been changed by recent developments. Any proposal to abandon history should be rejected. It is a question of "how much" and "what kind" of history is needed to help a pupil begin to understand the world in which he lives.

A fourth question relates to the larger issues of stability and change and curriculum construction. There are those who advocate going back to the history-geography-civics curriculum of an early day and there are equally earnest reformers who ask for a curriculum based completely on a study of contemporary society. The story of science need not greatly alter the general chronology of history. Some attention to the appearance and growth of scientific ideas may well replace some of the political and military events in the present narrative. The study of the people of the world in geography would not be altered greatly by calling attention to the role of science and technology in altering ways of living in some lands and the relatively slight impact of these forces among other peoples. There is little to be gained by throwing out the whole curriculum as outmoded and probably less by regarding the present curriculum as sacrosanct. A fruitful search for new content and experiences to help pupils reach their educational objectives is not aided by name-calling and emotional tirades. Careful scholarship and a clear view of educational needs are required to create a new design which will include elements of traditional stability and the more important aspects of contemporary change.

Closely akin to the tradition versus change argument, is the problem of giving more attention to intellectually gifted pupils. The case for special classes and special courses for the intellectually gifted is argued on the grounds that the gifted are the future leaders, creators and inventors. Since the gifted learn quickly and easily an assignment made for average pupils, a great deal of their time is wasted waiting for their less able and less eager classmates to complete assignments. The need for more scientists and the fact that many scientists make their most important discoveries before they are 30 years old lends urgency to the proposals for special programs for the gifted.

Educators have always recognized individual differences and have attempted to provide more difficult assignments or additional work for the rapid learners. Such a program is hard to operate under the best conditions and impossible to carry on with large classes and few teaching materials. The best classroom programs stress a higher quality of learning for the fast learner rather than more of the same thing. Such a program calls for a large library, a good librarian and a teacher, well trained in the subject field and with the energy and know-how to teach two or three separate groups in a single classroom. The limitations described have made for poor practice of a fine theory.

The major efforts to build special programs for the intellectually gifted have been made in English, mathematics and science. The objectives of the social studies are for citizenship, and the fact that all pupils are expected to be good citizens has tended to keep the interest of social studies teachers on a good over-all job for all pupils. There is wide agreement, however, that more imagination should be used in preparing courses of study to liberate the intellectual energies of gifted pupils in social studies classes. When such courses are prepared, experiences designed to show the relationships between scientific advance and social action may furnish one area where the interests of gifted pupils can be used to help them understand the ways in which modern science influences modern culture.

One final curriculum problem which runs through all the others is the considerable confusion as to what kind of individual the social studies curriculum is supposed to help produce. A curriculum is not an end in itself, but merely an instrument for the education of boys and girls. The question which faces the curriculum makers is, What kind of boy or girl do we hope to help shape by means of this curriculum? This question is not easy to answer. One answer is that the social studies should help the pupil make the adjustments which are necessary for modern living. He should learn how to find a job and hold it; how to find a mate and rear a family; how to function as a democratic citizen in a free society. The course designed for this end often includes experiences in etiquette, safety, a study of occupations and a study of civic and social problems at firsthand in the local community. The graduates from such a program are expected to have some common, civic competencies, at least a minimum of *savoir faire,* adequate social skills and some insight into themselves and the social, civic and economic groups in which they will live and work.

Opponents of this kind of curriculum complain about the emphasis on the trivial or the obvious. Such a curriculum, say these critics, is an attempt to project a nursery school program through elementary and secondary education. Such a program, they say, is strong on social adjustment, but weak on intellectuality which should be the first concern of any school. Particularly do they stress the necessity that Americans today know the great tradition of Western European and American culture, have knowledge of the other peoples of the world and their cultures, know how our government operates and how the economy functions. In short, the charge is that know-how about less important functions of our national life is the aim of education rather than acquiring knowledge about the vital ideas that form the very foundations of our national existence.

To the skilled social studies teacher the problem should not be as difficult as the sometimes bitter debate makes it sound. Most social studies teachers are working for the same general outcomes. Three such outcomes can be stated here:

1. It is the purpose of the social studies curriculum to aid in the development of individuals who can think critically and constructively. This objective has already been discussed under the head of method. It has the respect of scholars as well as educators interested in methods. The scholar has been defined as man thinking. The application of the scholar's way of thinking to the solution of the never-solved and ever-changing problems of human society is a dream as old as education.

But the scholar's way of thinking is closely linked to content. Facts, hypotheses, generalizations and principles come from content areas. Knowledge is acquired as the thinking process is developed and both are important.

2. The social studies curriculum should help develop individuals who have

sound attitudes concerning themselves and their relationships with other people, and about the society in which they live. Sound attitudes are as essential as knowledge and the ability to think. Patriotism should be firmly anchored to a reasoned understanding as to *why* America is great and *why* the American way of life is worthwhile. One of the goals of the social studies is to turn out pupils with the ability and the will to build firm loyalties on well-reasoned intellectual principles.

3. The social studies curriculum should help individuals learn to discipline themselves by harnessing their knowledge and their attitudes to the willingness to take action. Understanding and intellectual acceptance is not enough. It is the individual who is willing to act on his convictions, who really affects the society in which he lives. If the convictions are of high quality when measured by humanitarian and democratic criteria he affects society for the better—if they are not, he affects it for the worse. Our faith in free public education as a necessary adjunct of the democratic way of life is justified when graduates of the schools are able and willing to use their knowledge, through democratic means, to improve the society in which they live.

Much of the significance of these three purposes of the social studies curriculum lies in the order of precedence in which they have been presented here. Learning to think critically and constructively is regarded by most teachers as a unique and mandatory obligation of public education. Teaching pupils to think will not and, for the most part, cannot be done by any other social agency. On the other hand many other agencies in our culture share with the school the responsibility for developing sound attitudes and the willingness to take action based in knowledge and attitudes. Much of the know-how for living is learned by the actual living in a culture. The home, the church, community agencies of various kinds, political groups, the mass media of communication and agencies of government at all levels are institutions specially engaged in developing attitudes, disseminating information and organizing action programs. The school must contribute to all these three purposes. It is a question of priority, and the school's first obligation is to discharge its unique function of teaching pupils to think critically and constructively. However, its work need not stop there and even this prior task may be best accomplished by blending the three purposes into their proper proportions in the curriculum.

How can a better understanding of science and scientists help social studies teachers to accomplish these three purposes? The method of critical thinking is perhaps best illustrated in all of its complex details in the stories of great scientific discoveries. The battle for freedom to think, inquire, investigate has been an integral part of the story of the growth of scientific knowledge. The many uses of knowledge from laboratories in clinic, factory, farm and home are concrete examples of knowledge and work. The substitution of scientific knowledge for superstition and folklore is a less concrete but equally dramatic example of the role of scholarship in replacing hunches and rule-of-thumb ways of living with verified knowledge. Finally, the biographies of the scientists give numerous stories of men and women whose lives had purposes and direction. They made commitments which they fulfilled in a lifetime of laboring to advance the scientific knowledge which we inherit today for our better comfort, safety and general well-being.

In the task of revising the school curriculum, the place of the social studies in the total school curriculum should be the central question.

In future revisions of the total school problem there will be continued, or increased, emphasis on English and increased emphasis on mathematics and science. This does not mean that the only hope lies in integrated or core curriculum programs or other grand designs for insuring a unified general education for all pupils. Teachers with good training in one subject field and all of the good intentions in the world find the job of building a sound instructional program in just one field difficult enough. At the same time the changes made in other subject programs frequently have relation to the social studies and these changes should be taken into account as the social studies curriculum is revised.

In the field of science there are many such overlapping areas. Astronomy has supplied us with our concept of the universe and the nature of the solar system. Geology has made its contribution along with scientific geography. New areas which are shared with other fields have been added to the social studies: conservation and public health which are taught in social studies and biology and chemistry; air-age education which is divided between science and social studies; and the whole area of safety which includes man's efforts to take civic action in order to live in some measure of safety with the machines created by science. Common efforts from the two areas should be dovetailed rather than overlapped in a general curriculum plan. It is probably a safe prediction that the growth of science and the increasing utilization of scientific data and methods will add steadily to the contiguous areas where science and the social studies both have some responsibility. Some knowledge of science will be essential to social studies teachers as these areas develop.

Social studies teachers should have a better understanding of the methods of science. Educational literature is filled with terms describing how pupils think and the kinds of minds with which they think. Critical thinking, problem-solving, the scientific method, geographical mindedness, historical mindedness are a few of the ways of thinking and the kinds of thinking techniques we hope to develop. There are probable differences in terminology but basically all of these terms describe man's attempts to use his intelligence for understanding the world in which he lives and the people who share his global habitat. Since this is true, teachers in all subject fields might do well to begin by accentuating the likenesses rather than the elements of uniqueness.

Finally, during the last generation an increasing volume of writing has come from the pens of scientists and mathematicians on the subject of education which has great significance for the social studies program. Bertrand Russell, A. N. Whitehead, James Conant, Vannevar Bush, the Comptons and many others have achieved educational statesmanship. To ignore the ideas of these men is to risk becoming archaic. If the social studies care to assume the risk of becoming archaic in a society where science and technology are becoming increasingly important they should do so with the knowledge that in a crowded curriculum the archaic soon becomes extinct.

Appendix

Social Aspects of Science

Preliminary Report of AAAS Interim Committee

Editor's Note.—*The following report by a special committee of the American Association for the Advancement of Science (AAAS) is reproduced from* Science, *January 25, 1957, with the kind permission of the publishers. This significant report by a group of scientists was presented at the December 1956 meeting of the AAAS where it attracted considerable attention among both scientists and the press. It is reproduced here because it ties in with the theme of this Yearbook and it represents some of the thinking being done by scientists on this important problem. Social studies teachers will find much here that is of concern to them as they consider their responsibilities in relation to the scientist.*

The council of the American Association for the Advancement of Science, at its 1955 meeting, resolved to establish an "Interim Committee on the Social Aspects of Science." During the past year this committee has made a preliminary study of the present state of science in the United States and its relation to social forces and issues. The committee found that even a cursory examination of this question leads to a serious conclusion: that there is an impending crisis in the relationships between science and American society. This crisis is being generated by a basic disparity. At a time when decisive economic, political, and social processes have become profoundly dependent on science, the discipline has failed to attain its appropriate place in the management of public affairs.

The committee believes that this question demands the most urgent attention of the AAAS and of scientists generally. The present interim report is not intended as a complete consideration of the many interrelated problems encompassed by the area which the committee has studied. Rather, the report represents a sampling of some of the issues

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Members of the committee are Ward Pigman, associate professor of biochemistry, University of Alabama Medical Center, *chairman;* Barry Commoner, professor of botany, Washington University; Gabriel Lasker, associate professor of anatomy, Wayne State University; Chauncey D. Leake, professor of pharmacology, Ohio State University; Benjamin H. Williams, Industrial College of the Armed Forces.

which the committee has found to serve as useful points of departure in developing an analysis of the situation. Because of the importance of this matter, the committee believes that any decision on the manner in which the AAAS can best deal with it should be based on extended and broadly conducted discussion among natural and social scientists and other interested persons. The report which follows is intended as one means of initiating this discussion.

Such an undertaking comes at an opportune time. We are at the start of a period in which science holds the promise of making unprecedented improvements in the condition of human life. Any action taken now to assist the orderly growth and beneficial use of science will be of lasting significance.

New Scientific Revolution

A cursory examination shows that society has become far more dependent on science than ever before for the following reasons.

Accelerated growth of scientific activity. The volume of scientific research and development conducted in this country has been increasing at an astonishing rate. In 1930, expenditures for science were estimated at $166 million; in 1953, the amount was more than $5 billion. Allowing for the change in the value of the dollar, this represents approximately a 15-fold increase in research expenditures over the 23-year period. The number of active scientists in the United States in 1930 was 46,000; the present number is probably about 250,000. All estimates of future needs for scientific research and personnel indicate that this growth will continue at an accelerated pace. This rate of growth sets scientific activity apart as the second most rapidly expanding sector of our social structure, military activities being first.

Increased use of scientific knowledge. It is characteristic of the present era that the previously formidable gap between scientific knowledge and its application to practical problems has become considerably reduced. It is now commonplace that calculations based on physical theory move quickly from the scientist's laboratory across the engineer's drafting board and on to actual industrial production. Since 1940 we have experienced a series of classic examples of almost immediate conversion of a scientific advance to a process of large practical impact upon society: antibiotics, synthetic polymers, nuclear energy, transistor electronics, microwave techniques, electronic computers. The greatly narrowed gap between laboratory and factory results from a distinctively new role of research in industry. Scientific investigations were previously regarded by industry as a kind of exotic garden to be cultivated in the hope of producing an occasional rare fruit. In contrast, research has now become a deliberate instrument of industrial development; scientific investigations are consciously undertaken as a means of achieving desired economic gains or, as in several notable industrial laboratories, for the purpose of contributing to our fund of basic scientific knowledge.

Recent advances in science have also created completely new industries. Four major industries—chemical, electronic, nuclear energy, and pharmaceutical—represent direct extensions of laboratory experience to an industrial scale. This type of direct transformation of scientific experience to industrial operation is probably unique in human history. Earlier industrial developments were based more on empirical experience than on laboratory science.

Social Position of Science

Science is but one sector of our culture. It is one of the institutions of society, and to a considerable degree society itself governs the development of science. In the present situation, social forces influence the development of science in the following key ways.

Social demand for technologic advances. From the evidence already cited it is clear that there is a strong social demand for at least some kinds of scientific progress. The fact that industry has made unprecedented investments in research is practical evidence that this type of scientific work is seen as a desirable activity by industrial managers. Government scientific activity, which perhaps reflects a wider range of social forces, has also been very intense in the past 20 years. Accelerated support for scientific research is evident from the increased scale of military research, the growing activities of the National Science Foundation, the greatly increased support for medical research by the National Institutes of Health, and the increasing share of philanthropic funds from private agencies now devoted to research on health and social problems. The following generalizations may be made concerning the distribution of the enhanced research support now enjoyed by American science.

1) The major part of research support goes into applied research and development rather than into basic science. In industrial research, the ratio is about 97/3; in universities, about 50/50; in federal agencies (including support for research done elsewhere) about 90/10.

2) Support is heavily slanted toward physical sciences. In 1954, federal research support was divided as follows: physical sciences, 87 percent; biological sciences, 11 percent; social sciences, 2 percent. Industrial research is at least as heavily weighted in this direction.

3) At present a very large part of our total research activities are for

military purposes. Of the estimated federal expenditures for research in 1957 ($2.5 billion), about 84 percent is earmarked for matters related to national security.

4) Colleges and universities, which are the site of much of our basic research activities, have become dependent on federal funds for the greater portion of their research support (60 to 70 percent in 1954).

Some of the effects of these factors upon the character of scientific research are discussed in the section on "Internal situation in science."

Public interest in science. There are indications that the public interest in science is not commensurate with the important role of science in society.

1) Shortage of scientific personnel: We face a major crisis with respect to present and future shortages of scientific personnel. In effect, this means that he social environment in the United States does not elicit a maximum interest in science on the part of those individuals who have the capability of doing scientific work, or that our social organization does not permit them to receive the necessary training. This problem is closely connected with the more general question of the present state of public education in the United States. The content of public education has been subjected to a good deal of criticism recently, especially with regard to science and mathematics. Many scientists feel that an official state requirement for graduation from high school which calls for 1 year of "general" mathematics and for 1 year of "general" science cannot be regarded as proper recognition of the importance of science.

2) Attitudes toward scientific work: To some degree the foregoing difficulties reflect a broader problem—that is, a traditional disregard for abstract thinking. More than a century ago De Tocqueville observed, "Hardly anyone in the United States devotes himself to the theoretical and abstract portion of human knowledge." He said that the immediately practical aspects of life were, however, fully appreciated. The same generalization appears to be true today. So-called "practical" men of public affairs and business frequently disregard the advice of scientists and prefer instead to rely on "common sense," but the latter is often construed to mean what Einstein has called "a deposit of prejudices laid down in the mind prior to the age of 18." This problem, particularly as it relates to a lack of interest in scientific careers, has attracted considerable attention of late. Recent surveys indicate that the general attitude exemplified by popular epithets such as "eggheads" and "longhairs" is well rooted in the opinions of young people.

3) Science in the public press and other media: By all standards, science receives an unduly small share of the budget of newspaper space or broadcasting time. The number of books and magazines devoted to disseminating public information about science is correspondingly small. The immediate reasons for this state of affairs are manifold. It is clear, however, that the situation reflects a rather low level of interest in science on the part of the public, or, more probably, of those who attempt to judge the public mind for purposes of directing the media of information.

Internal Situation of Science

How has its recently accelerated rate of growth and the general nature of the social influences upon it affected the character of American science? Some brief and approximate answers may be made.

Unbalanced growth. The growth of our scientific organization has not been an orderly process. Growth has been based less on internal needs of science than on the interest of external agencies in possible practical results. In a sense, the speed and direction of the development of science has been determined by the users of science rather than the practitioners of science. Agencies which use scientific knowledge (for example, industrial management, military establishments, medical agencies) have undertaken to encourage, and pay for, scientific research of a sort which seems to promise information that might be useful to their own specific purposes. This disproportionate growth of the physical sciences as compared with biological and social sciences to some degree reflects the interests and superior financial resources of the industrial and military agencies that support science.

The effects of this unbalanced development are already being felt. Generally speaking, we sometimes find ourselves embarking upon new ventures, based on advances in chemistry and physics, before we are adequately informed about their consequences on life or on social processes. Some of the resultant difficulties which we have already made for ourselves are described in the section on "Major social issues of scientific origin: signs of trouble."

It should be recalled that this unbalanced growth takes place within the framework of a shortage of personnel. This situation has very naturally given rise to a somewhat disorganized competition for students, which further accentuates the disparate pattern of development of the various sciences.

Inadequate progress in basic research. It is well known that the creative source of all technologic advance is the free inquiry into natural phenomena that we call basic, or "pure," science. However, as has already been indicated, the great bulk of our present research activities represent the development of practical applications of the knowledge generated by previous advances in pure science. It has been pointed out repeatedly that many of our current technologic advances are based on the application of accumulated basic knowledge which is perhaps 20 to 30 years old. The progress of basic science does not appear to be keeping pace with the development of applied science. Some observers even feel that there has been an absolute decline in the amount of highly creative research of the type that leads to major advances in our knowledge of nature. They point out that our present understanding of the structure of atoms and molecules and of the behavior of living cells goes back to great illuminating propositions that are 25 years or more old.

Difficulties in scientific communication. New information is the major goal of scientific research, and communication of information is vital for all scientific progress. However, the rapid, rather disordered growth of science has placed a severe strain on the channels of scientific communication.

1) Communication among the divisions of science: The problem of adequate dissemination of the results of current research has become a matter of great concern. The growth of our research establishment and the resulting increase in the numbers of scientific communications have made the problem of "keeping up with the literature" quite serious. It is now widely recognized by scientists that the existing system of publication and distribution does not fill their needs. Published articles and monographs have not kept up with the current knowledge in many fields. The number of journals is insufficient (publication delays of 1 year are common) and methods of abstracting, indexing, and reviewing are inadequate. It is becoming rapidly more difficult for scientists to find out what their colleagues know. The situation is particularly bad with respect to articles printed in foreign languages (Russian, especially) which investigators are too frequently incapable of reading. Some observers have already urged the establishment of scientific information centers from which subscribers could receive transmitted reproductions of teletyped abstracts obtained by electronic scanning devices. Such centers would require government investment of about $150 million. That proposals of this magnitude are under current discussion is an indication of the severity of this problem.

Proper communication among scientists is not, however, merely a matter of developing proper recording, cataloging, and searching devices. Face-to-face meetings, which bridge the barriers of specialization, are an obvious necessity for the ordered growth of human knowledge. There is a widespread feeling among scientists that scientific meetings which bring together investigators from different fields of science are a necessity. But, with some distinguished exceptions, such meetings have been difficult to establish thus far.

2) Imposed restrictions of free communication: Although government support has been a major source of recent scientific growth, it has been accompanied by influences which are in some respects inimical to the basic needs of science. Complete freedom of comunication, regardless of national boundaries, is an essential aspect of science; nevertheless, along with government support American science has been burdened with practices that restrict the free flow of information. The interchange of scientific information is sometimes restricted unduly by the overclassification of data that affect national security. It must be acknowledged that at certain times, and with certain types of data, restriction of exchange of information is necessary, so long as scientific progress continues to have military activity as one of its chief values. The immediate problem is to limit such restrictions to a minimal area. The ultimate problem is to free society as a whole and thereby science itself from the tyranny of war.

Not all artificially imposed restrictions on communication result from government requirements. There is an understandable tendency on the part of industry to protect its investment in research by restricting distribution of its results. As a greater share of research is taken on by industry, especially in those areas where expensive, complex operations are involved, this problem will become of greater significance. It is ironical to note that a recent Conference on the Practical Utilization of Recorded Knowledge—Present and Future (at Western Reserve University, January 1956), which devoted a good deal of attention to the problem of improved dissemination of knowledge, found it necessary to hold part of its deliberations behind closed doors and to refrain from publicizing the full record of these "confidential" sessions [*Am. Scientist* (April 1956)].

Unrestricted communication is but one facet of the free intellectual environment that is as important to scientific creativity as it is to all other fields of human endeavor. If society is to benefit broadly and effectively from the efforts of modern science, and if science in turn is to be enriched by contributions from other fields, the social order must provide the greatest possible intellectual, social, and personal freedom for scientist and nonscientist alike at every level of the social structure.

Major Social Issues of Scientific Origin: Signs of Trouble

How well have we solved those social issues which are most closely related to scientific or technologic knowledge? Most of our successes are self-evident. Scientific knowledge is being applied to the development of a new industrial system capable of greatly increasing, in both quantity and quality, the total wealth of man. We are creating a remarkable establishment for medical and related research, which has given us mastery of many human ills and has prolonged the span of life. Nevertheless, scientific problems which influence social processes have become an arena of serious difficulties. In some situations our enhanced ability to control nature has gone awry and threatens serious trouble. Some examples follow.

Radiation dangers. It is hardly necessary to point out at this time that the difficulties created by the dispersion of radioactive materials from nuclear weapons have caused considerable concern in this country and throughout the world. Regardless of one's attitude toward the necessity of setting off nuclear explosions for testing purposes, there is considerable evidence that this aspect of human control over nature is a potential danger to life. The recent controversy over the immediate significance of this problem shows that we have not yet developed methods for the orderly determination of the facts, in an area in which such facts may influence the health of the whole population of the earth.

Food additives. The enormous growth of industry based on organic synthesis, coupled with the already mentioned tendency toward rapid exploitation of scientific knowledge, has resulted in a great increase in the number of man-made compounds now used in foods or otherwise ingested or absorbed by human beings. The period of use of many of these substances has been rather short, and possible undersirable long-range biological effects have not yet had time to appear. Laboratory methods for studying delayed biological effects such as carcinogenicity are unfortunately difficult to manage and equivocal in interpretation. Consequently, the establishment of certification procedures which might assure the public that a given additive is harmless is a difficult matter which has been the subject of considerable discussion and controversy. Nevertheless, additives are in use, and the problem of making a reasonable determination of their safety must be faced.

A parallel situation exists in connection with the health hazards that arise from the dissemination of fumes, smogs, and dusts by industrial plants and from automotive and other combustion processes. The harmful biological effects of these agents usually appear a long time after the commercial usefulness of the process is established and large-scale operations are in effect. By then remedial procedures are very difficult to carry out.

In these cases the use of substances resulting from scientific advance has already outstripped the base provided by our scientific knowledge. Information on the biological effects of a new substance is acquired at a very much slower pace than the rate at which new substances are made or put into use. It is probably inevitable that biological research will move more slowly than either chemistry or physics, but it should be expected, therefore, that we would put correspondingly more effort into research on biological phenomena. The opposite is the case. Less than about 10 percent of our total research expenditure goes into biology and medicine.

Natural resources. The natural resources contained in the crust of the earth comprise the major source of our wealth, and it is a matter of concern that they be properly used. The natural laws which regulate the character and behavior of these resources lie within the domain of the various sciences. However, social decisions actually control what is done with our resources. It has been pointed out by Paul B. Sears that these decisions are rarely in the hands of scientists. Under these circumstances large-scale changes in our natural resources have occurred without proper consideration for the consequences which might be expected from a knowledge of natural laws.

An illuminating example cited by Sears is the recent flood disaster in New England. He points out that the widespread damage caused by these floods was a direct consequence of the unplanned crowding of housing areas into the river flood-plains. This was a failure to recognize and act upon physical events easily foreseeable from a relatively simple knowledge of the landscape. The declining water-table caused by irrigation practices illustrates a similar disregard for natural laws. In these and more complex instances, the harmful outcomes of the given practice can be predicted by appropriate technical analysis.

These examples show that social factors condition the use to which scientific knowledge is put. Perhaps the most striking example of this phenomenon is modern warfare, which represents a social decision to use the power of scientific knowledge for purposes of destruction and death.

Some Conclusions

The present state of science and its relation to the social structure of which it is a part are characterized by the following general features.

1) We are witnessing an unprecedented growth in the scale and intensity of scientific work. Research has placed in human hands the power to influence the life of every person in every part of the earth.

2) This growth has been stimulated by an intense demand for the practical products of research, especially for military and industrial use. Agencies which use the products of research are willing to provide financial support and other forms of encouragement for science but show a natural tendency to favor those fields and aspects of science which most nearly relate to their needs.

3) The public interest in, and understanding of, science is not commensurate with the importance that science has attained in our social structure. It cannot be said that society provides good conditions for the proper growth of science. The effort to explain the nature of science to the public is slight compared with the public attention now given to other less consequential areas of human activity. Interest in science as a career is so restricted that a serious and worsening personnel situation has arisen.

4) For reasons such as those just cited, science is experiencing a period of rapid but rather unbalanced growth. Basic research, which is the ultimate source of the practical results so much in demand, is poorly supported and, in the view of some observers, lacks vigor and quality. Areas more remotely connected with industrial and military applications, such as biology and the social sciences, are also not being adequately supported. The present period of rapid, unplanned growth in research activities is precipitating critical difficulties in connection with the dissemination and analysis of scientific information.

5) The growth of science and the great enhancement of the degree of control which we now exert over nature have given rise to new social practices, of great scope and influence, which make use of new scientific knowledge. While this advance of science has greatly improved the condition of human life, it has also generated new hazards of unprecedented magnitude. These include the dangers to life from widely disseminated radiation, the burden of man-made chemicals, fumes, and smogs of unknown biological effect which we now absorb, large-scale deterioration of our natural resources, and the potential of totally destructive war. The determination that scientific knowledge is to be used for human good or for purposes of destruction is in the control of social agencies. For such decisions, these agencies and ultimately the people themselves must be aware of the facts and the probable consequences of action. Here scientists can play a decisive role: they can bring the facts and their estimates of the result of proposed actions before the people.

Need for Action: the Role of the Organizations of Science

This appears to be a critical time for review of the general state of science and its relation to society. We are now in the midst of a new and unprecedented scientific revolution which promises to bring about profound changes in the condition of human life. The forces and processes now coming under human control are beginning to match in size and intensity those of nature itself, and our total environment is now subject to human influence. In this situation it becomes imperative to determine that these new powers shall be used for the maximum human good, for, if the benefits to be derived from them are great, the possibility of harm is correspondingly serious.

As scientists we are particularly concerned with determining how we should meet this situation, both as individuals and through our organizations. In marked contrast to other associations, scientific societies seldom consider the social and economic position of their group. Action taken on social problems with a scientific or technologic base are sporadic and usually forced. Yet the democratic system is operated to a considerable extent under stimulus from groups, each representing the views and interests of its members.

Business and labor are not backward in presenting their opinions on social questions that affect them. They make sure that in the final decision their views have been considered. There are many who think that the viewpoint of scientists should also be stated publicly. In fact, if others express their opinions and scientists do not, a distorted picture will be presented, a picture in which the importance of science will be lacking and the democratic process will become to that extent unrepresentative.

The need for action is serious and immediate. Consider, for example, the situation related to the biological hazards of radiation. It is now 6 months since the radiation committees of the National Academy of Sciences issued a report that called for a series of immediate actions including, among others: (i) the institution of a national system of radiation exposure record-keeping of all individuals; (ii) vigorous action to reduce medical exposure to x-rays; (iii) establishment of a national agency to regulate disposal of radioactive wastes; (iv) establishment of an international program of control and study of radioactive pollution of the oceans; (v) considerable relaxation of secrecy about dissemination of radioactivity. In addition, the committees pointed out that "The development of atomic energy is a matter for careful integrated planning. A large part of the material that is needed to make intelligent plans is not yet at hand. There is not much time left to acquire it."

There is no evidence that these urgent pleas for action have yet met with any significant response. Clearly, this is a matter that requires the persistent attention of all scientists. It exemplifies the pressing need that scientists concern themselves with social action. In this situation, the AAAS carries a special responsibility. As one of our past presidents, Warren Weaver, has said: "If the AAAS is to be a vigorous force for the betterment of science, it cannot continue in the face of crucial situations with closed eyes and a dumb mouth." This responsibility has already been recognized. What is needed now is a way to meet it.

Contributors' Who's Who

Blough, Glenn O., is Associate Professor of Education at the University of Maryland. He is past president of the National Council for Elementary Science and President of the National Science Teachers Association. He is author of *Elementary School Science and How to Teach It, Making and Using Classroom Science Materials* as well as author of several widely used textbooks in elementary school science and trade books in science for children. Five of his titles have been Junior Literary Guild selections. He has contributed articles to many professional magazines. For eight years he was Specialist for Science in the U. S. Office of Education.

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Kramer, S. Paul, is associated with the National Academy of Sciences as a member of the Secretariat of the U. S. National Committee for the International Geophysical Year. During the war he served as a lieutenant in the U. S. Navy as an operational intelligence officer in the South Pacific. He is presently on leave from the Firm of Auerbach, Pollak and Richardson, members of the New York Stock Exchange, and from his duties as board member and officer of Panama Cooperative Fisheries and Corporacion Industrial to participate in the IGY program.

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Tager, Harold, free-lance writer, formerly with the Office of Research Information, National Institutes of Health, and formerly on the staff of several national magazines.

Todd, Lewis Paul, is editor of *Social Education*. He has taught social studies at various grade levels and in a number of educational institutions including private preparatory school, public high school, teachers college, liberal arts college, and university, and he has served on the staff of the NEA Committee on International Relations. He is the author (with Kenneth Cooper) of the elementary school series of textbooks, *Man's Ways and Times*, and (with Merle Curti) of the high school textbook, *America's History*. He writes regular weekly editorials for the Civic Education Service's publication *The Civic Leader*, and has contributed articles to a number of professional publications.

General Reference

Deason, Hilary J. ***Books of the Traveling High School Science Library.*** **Revised edition. American Association for the Advancement of Science. Washington, D. C.: the Association, 1956. Price 25 cents.**

This is an annotated bibliography of 200 books on science that for the most part are not highly technical. The list was designed to serve as suggested recreational or collateral reading in the sciences and mathematics. The books in this bibliography are well written and interesting, and are suitable for general reading. Biographies and autobiographies, histories of science and mathematics, and books on applied science are well represented in the collection. An attempt has been made to provide a very broad range of subject matter. As a rule textbooks are not included though there are a few exceptions to this.

Most of the books have been chosen because of their special appeal to the general reader who has little or no background in science or mathematics.

This list should be a helpful source for general reading in the sciences and mathematics for social studies teachers and pupils.